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

July 14, 2022

Ms. Nicole L. Flippin
H. B. Robinson Steam Electric Plant
Site Vice President
Duke Energy Progress, LLC
3581 West Entrance Road, RNPA11
Hartsville, SC 29550

SUBJECT: H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2 – CLOSEOUT OF GENERIC LETTER 2004-02, “POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS” (EPID L-2017-LRC-0000)

Dear Ms. Flippin:

The U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2004-02, “Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors” dated September 13, 2004, requesting that licensees address the issues raised by Generic Safety Issue (GSI)-191, “Assessment of Debris Accumulation on PWR [Pressurized Water Reactor] Sump Performance.”

By letter dated May 14, 2013, Duke Energy Progress, LLC (licensee) stated that they will pursue Option 2 (deterministic) for the closure of GSI-191 and GL 2004-02 for H.B. Robinson Steam Electric Plant, Unit 2 (Robinson). On July 23, 2019, GSI-191 was closed. It was determined that the technical issues identified in GSI-191 were now well understood and therefore GSI-191 could be closed. Prior to and in support of closing the GSI-191, the NRC staff issued a technical evaluation report on in-vessel downstream effects (IVDEs). Following the closure of GSI-191, the NRC staff also issued review   uidancee for IVDEs, “NRC Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of GL 2004-02 Responses,” to support review of the GL 2004-02 responses.

The NRC staff has performed a thorough review of the licensee’s responses and requests for additional information (RAI) supplements to GL 2004-02. Based on the evaluations, the NRC staff finds the licensee has provided adequate information as requested by GL 2004-02. The stated purpose of GL 2004-02 was focused on demonstrating compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) 50.46. Specifically, GL 2004-02 requested addressees to perform an evaluation of the emergency core cooling system and containment spray system recirculation and, if necessary, take additional action to ensure system function in light of the potential for debris to adversely affect long-term core cooling.

The NRC staff finds the information provided by the licensee demonstrates that debris will not inhibit the emergency core cooling system or containment spray system performance following a postulated loss-of-coolant accident. Therefore, the ability of the systems to perform their safety functions, to assure adequate long term core cooling following a design-basis accident, as required by 10 CFR 50.46, has been demonstrated.

Therefore, the NRC staff finds the licensee's responses to GL 2004-02 are adequate and considers GL 2004-02 closed for Robinson.

Enclosed is the summary of the NRC staff's review. If you have any questions, please contact me at (301) 415-1387 or by e-mail at Tanya.Hood@nrc.gov.

Sincerely,

/RA/

Tanya E. Hood, Project Manager
Plant Licensing Branch II-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-261

Enclosure:
NRC Staff Review of GL 2004-02

cc: Listserv

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

U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW

OF THE DOCUMENTATION PROVIDED BY

DUKE ENERGY PROGRESS, LLC

FOR H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2

CONCERNING RESOLUTION OF GENERIC LETTER 2004 02

POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION

DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

DOCKET NO. 50-261

1.0 INTRODUCTION

A fundamental function of the emergency core cooling system (ECCS) is to recirculate water that has collected at the bottom of the containment through the reactor core following a break in the reactor coolant system (RCS) piping to ensure long-term removal of decay heat from the reactor fuel. Leaks from the RCS, hypothetical scenarios known as loss-of-coolant accidents (LOCAs), are part of every plant’s design basis. Hence, nuclear plants are designed and licensed with the expectation that they are able to remove reactor decay heat following a LOCA to prevent core damage. Long-term cooling following a LOCA is a basic safety function for nuclear reactors. The recirculation sump provides a water source to the ECCS in a pressurized-water reactor (PWR) once the primary water source has been depleted.

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

It is also possible that some debris would pass through (termed “bypass”) the sump strainer and lodge in the reactor core. This could result in reduced core cooling and potential core damage. If the ECCS strainer were to remain functional, even with core cooling reduced, containment cooling would be maintained, and the containment function would not be adversely affected. Findings from research and industry operating experience raised questions concerning the adequacy of PWR sump designs. Research findings demonstrated that, compared to other LOCAs, the quantity of debris generated by a high-energy line break (HELB) could be greater. The debris from a HELB could also be finer (and thus more easily transportable) and could be comprised of certain combinations of debris (i.e., fibrous material plus particulate material) that could result in a substantially greater flow restriction than an equivalent amount of either type of debris alone. These research findings prompted the U.S. Nuclear Regulatory Commission (NRC or the Commission) to open Generic Safety Issue (GSI) - 191, "Assessment of Debris Accumulation on PWR Sump Performance," in 1996. This resulted in new research for PWRs in the late 1990s.

GSI-191 focuses on reasonable assurance that the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.46(b)(5) are met. This deterministic rule requires maintaining long-term core cooling (LTCC) after initiation of the ECCS. The objective of GSI-191 is to ensure that post-accident debris blockage will not impede or prevent the operation of the ECCS and CSS in recirculation mode at PWRs during LOCAs or other HELB accidents for which sump recirculation is required. The NRC completed its review of GSI-191 in 2002 and documented the results in a parametric study that concluded that sump clogging at PWRs was a credible concern.

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

After completing the technical assessment of GSI-191, the NRC issued Bulletin 03-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors," on June 9, 2003.[1] The Office of Nuclear Reactor Regulation (NRR) requested and obtained the review and endorsement of the bulletin from the Committee to Review Generic Requirements (CRGR).[2] As a result of the emergent issues discussed in Bulletin 03-01, the NRC staff requested an expedited response from PWR licensees on the status of their compliance of regulatory requirements concerning the ECCS and CSS recirculation functions based on a mechanistic analysis. The NRC staff asked licensees who chose not to confirm regulatory compliance, to describe any interim compensatory measures that they had implemented or will implement to reduce risk until the analysis could be completed. All PWR licensees responded to Bulletin 03-01. The NRC staff reviewed all licensees' Bulletin 03-01 responses and found them acceptable.

In developing Bulletin 03-01, the NRC staff recognized that it might be necessary for licensees to undertake complex evaluations to determine whether regulatory compliance exists in light of the concerns identified in the bulletin and that the methodology needed to perform these evaluations was not currently available. As a result, that information was not requested in Bulletin 03-01, but licensees were informed that the NRC staff was preparing a Generic Letter (GL) that would request this information. GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004,[3] was the follow-on information request referenced in Bulletin 03-01. This document set the expectations for resolution of PWR sump performance issues identified in GSI-191, to ensure the reliability of the ECCS and CSS at PWRs. NRR requested and obtained the review and endorsement of the GL from the CRGR.[4]

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[1] Agencywide Documents Access and Management System (ADAMS) Accession No. ML031600259
[2] ML031210035
[3] ML042360586
[4] ML040840034

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

By letter dated May 28, 2004,[5] the Nuclear Energy Institute (NEI) submitted NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology,"[6] which describes a methodology for use by PWR licensees in the evaluation of containment sump performance. This is also called the Guidance Report. NEI requested that the NRC review the methodology. The methodology was intended to allow licensees to address and resolve GSI-191 issues in an expeditious manner through a process that starts with a conservative baseline evaluation. The baseline evaluation serves to guide the analyst and provide a method for quick identification and evaluation of design features and processes that significantly affect the potential for adverse containment sump blockage for a given plant design. The baseline evaluation also facilitates the evaluation of potential modifications that can enhance the capability of the design to address sump debris blockage concerns and uncertainties and supports resolution of GSI-191. The report offers additional guidance that can be used to modify the conservative baseline evaluation results through revision to analytical methods or through modification to the plant design or operation.

By letter dated December 6, 2004,[7] the NRC issued an evaluation of the NEI methodology. The NRC staff concluded that the methodology, as approved in accordance with the NRC staff safety evaluation (SE), provides an acceptable overall guidance methodology for the plant-specific evaluation of the ECCS or CSS sump performance following postulated DBAs. Taken together NEI 04-07 and the associated NRC staff SE are often referred to as the Guidance Report SE.

In response to the NRC staff SE conclusions on NEI 04-07, the Pressurized Water Reactor Owners Group sponsored the development of the following Westinghouse Commercial Atomic Power (WCAP) Topical Reports (TRs):

- TR-WCAP-16406-P-A, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1, to address the effects of debris on piping systems and components.[8]

- TR-WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," issued March 2008,[9] to provide a consistent approach for plants to evaluate the chemical effects that may occur post-accident in containment sump fluids.[10]

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[5] ML041550661
[6] ML050550138 and ML050550156
[7] ML043280641
[8] ML073520295
[9] ML081150379
[10] ML073521072

- TR-WCAP-16793-NP-A, “Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid,” Revision 2 issued July 2013,[11] to address the effects of debris on the reactor core.[12]

The NRC staff reviewed the TRs and found them acceptable to use (as qualified by the limitations and conditions stated in the respective SEs). A more detailed evaluation of how the TRs were used by the licensee is contained in the evaluations below.

After the NRC staff evaluated licensee responses to GL 2004-02, the NRC staff found that there was a misunderstanding between the industry and the NRC on the level of detail necessary to respond to GL 2004-02. The NRC staff, in concert with stakeholders, developed a content guide for responding to requests for additional information (RAIs) concerning GL 2004-02. By letter dated August 15, 2007,[13] the NRC issued the content guide describing the necessary information to be submitted to allow the NRC staff to verify that each licensee’s analyses, testing, and corrective actions associated with GL 2004-02 are adequate to demonstrate that the ECCS and CSS will perform their intended function following any DBA. By letter dated November 21, 2007,[14] the NRC issued a revised content guide (hereafter referred to as the content guide).

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

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

Based on the interactions with stakeholders and the results of the industry testing, the NRC staff, in 2012, developed three options to resolve GSI-191. These options were documented and proposed to the Commission in SECY-12-0093, “Closure Options for Generic Safety Issue - 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance,” dated July 9, 2012.[15] The options are summarized as follows:

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[11] ML13239A114
[12] ML13084A154
[13] ML071060091
[14] ML073110389
[15] ML121320270

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

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

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

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

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

The options allowed industry alternative approaches for resolving GSI-191. The Commission issued Staff Requirements Memorandum SECY-12-0093 on December 14, 2012,[16] approving all three options for closure of GSI-191.

By letter dated May 14, 2013,[17] the licensee stated that they will pursue Option 2 (deterministic) for the closure of GSI-191 and GL 2004-02 for Robinson. On July 23, 2019,[18] GSI-191 was closed. It was determined that the technical issues identified in GSI-191 were now well understood and therefore GSI-191 could be closed. Prior to and in support of closing the GSI, the NRR staff issued a technical evaluation report on in-vessel downstream effects (IVDEs).[19] Following the closure of the GSI, the NRR staff also issued review guidance for IVDEs to support review of the GL 2004-02 responses.[20]

The following is a list of correspondence between the NRC and the licensee in response to GL 2004-02:

GL 2004-02 CORRESPONDENCE		
DOCUMENT DATE	ACCESSION NUMBER	DOCUMENT
March 4, 2005	ML050740377	Initial Response to GL
June 3, 2005	ML051520544	1st NRC RAI
July 19, 2005	ML052070685	Licensee Response to RAI
September 1, 2005	ML052490343	Supplemental Information
February 8, 2006	ML060370460	2nd NRC RAI
March 7, 2008	ML080730290	Licensee Response to RAI
July 25, 2008	ML081900649	3rd NRC RAI
December 17, 2008	ML083570469	Licensee Response to RAI
December 3, 2009	ML093310294	4th NRC RAI

[16] ML12349A378
[17] ML13141A283
[18] ML19203A303
[19] ML19178A252
[20] ML19228A011

March 30, 2010	ML100920053	Licensee Response to RAI
October 8, 2010	ML102860138	Supplemental Information
September 30, 2021	ML21273A365	Final Response
April 22, 2022	ML22112A148	5th NRC RAI
May 19, 2022	ML22139A149	Licensee Response to RAI

The NRC staff reviewed the information provided by the licensee in response to GL 2004-02 and all RAIs. The following is a summary of the NRC staff review.

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

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

- Replaced sump strainers with complex geometry strainers with filtering surface area over 4,000 square feet (ft^2).
- Replaced disaster bushing in containment spray pump seal with one compatible with downstream particulate debris.
- Sampled and characterized latent debris, including debris sources such as tags and labels, etc.
- Revised plant labeling procedure to preclude the replacement or introduction of any label made from material that could contribute to screen debris loading.
- Developed and documented debris generation and debris transport analyses.
- Documented ex-vessel downstream effects analysis.
- Documented NPSH analysis accounting for the new debris loaded strainer.
- Established a new lower spray additive tank level to minimize the generation of chemical debris.
- Established procedural controls to control aluminum and latent debris in containment within analyzed limits.
- Revised the insulation specification to control the insulation material and volume in the ZOI.
- Completed additional strainer bypass testing in 2013.

Based on the information provided by the licensee, the NRC staff considers this item closed for GL 2004-02.

3.0 BREAK SELECTION

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through December 17, 2008. The licensee considered the NRC SE guidance recommended types of breaks in selecting break scenarios for debris generation evaluation. The licensee's rationale for determining the largest potential for debris generation was that: (1) the greatest concentrations of insulation are located in reactor coolant pump (RCP) bays, (2) the largest pipe in the RCS loop is the 31-inch crossover leg pipe, and (3) the break location evaluation was varied along the crossover leg piping for each bay.

The licensee determined that the outlet of the steam generator leading to the RCP is the break with the largest potential for debris generation and that this location produces a ZOI that encompasses both the RCP bowl and the maximum quantity of steam generator insulation. Both the RCP and steam generator have large quantities of insulation. The NRC staff found that for the large ZOI materials, the selected break location clearly seems reasonable, e.g., the 17D for Nukon® or the 28.6D for the materials of unknown ZOI radii. Staff found however, that the applicability of this approach is less clear with respect to the 5.5D ZOI for calcium silicate (Cal-Sil).

The NRC staff noted that the crossover leg breaks at the steam generator outlet encompasses breaks with two or more different types of debris, breaks with the largest potential particulate to fiber ratios, and breaks with the potential to generate a thin bed layer of debris. The breaks with the most direct path to the sump would be a small-break LOCA (SBLOCA) occurring in the vicinity of the installed strainers but such breaks would not result in greater debris accumulation on the strainer than would the RCP bay large-break LOCAs (LBLOCAs). Recirculation would not be needed for secondary line breaks.

The licensee concluded that a LBLOCA in the crossover leg at the steam generator outlet within RCP C Bay would generate the maximum possible quantity of debris, while the same LBLOCA in RCP B Bay could generate the largest particulate debris loads and that these cases bound other cases. With respect to the potential thin bed formation, the break in RCP B Bay may have the greater potential to cause high head losses because this could produce the greater head losses due to the greater potential quantities of microporous insulation debris.

Based on guidance from NRC Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," Revision 4, dated March 2012,[21] Position 2.3.1.5, the following break locations were considered:

- Break No. 1 - Largest potential for debris: The RCP "C" Bay was determined to contain the largest amount of debris potentially generated by a LBLOCA.

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[21] ML111330278

- Break No. 2 - Large breaks with two or more different types of debris: The RCP “C” Bay was analyzed as the limiting case for Break No. 2.

- Break No. 3 - Most direct path to the sump: There are no small lines where a potential break could cause a greater amount of debris generation than a large break in the RCS loop piping.

- Break No. 4 - Largest potential particulate debris-to-insulation ratio: Therefore, RCP “B” Bay was analyzed as the limiting case for Break No. 4.

- Break No. 5 - Breaks that generate a Thin-Bed effect: For complex strainer designs, a 3/8-inch (in.) bed thickness was shown to form before any appreciable additional head loss attributable to the thin-bed effect was noted. It can be postulated that fibrous debris is generated and transported to the sump, followed by washdown of particulate latent debris, which potentially results in the thin-bed effect. Rather than analyzing specific LOCA scenarios, the thin-bed effect was incorporated into the head loss calculation.

Based on the information summarized above, the licensee concluded that a LBLOCA in the intermediate leg at the steam generator outlet within RCP “C” Bay generates the maximum possible quantity of debris, while the same LBLOCA in RCP “B” Bay generates the largest particulate debris load. SBLOCAs and other potential HELBs are bounded by these LBLOCAs. The NRC staff found that the licensee’s break selections are technically adequate.

NRC STAFF CONCLUSION:

For this review area, the licensee has provided sufficient information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. The break location analysis completed by the licensee is in accordance with the content guide and the Guidance Report SE while using an acceptable method to determine break locations to analyze for maximum debris generation results. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02 for Robinson.

4.0 DEBRIS GENERATION/ZONE OF INFLUENCE (EXCLUDING COATINGS)

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

NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through December 17, 2008. The licensee, in its debris generation/ZOI process, determined the zone within which the break jet forces would be sufficient to damage materials and create debris, and the amount of debris generated by the break jet forces. The licensee used the approved methodology default values.

The licensee’s evaluation provided destruction ZOIs and the basis for the ZOIs for each applicable debris constituent. It also provided the quantity of each debris type generated for each break location evaluated. The evaluation also provided the total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.

The licensee adopted the SE accepted ZOI radii of 17D for Nukon®, 11.7D for Temp-Mat™, and 5.5D for Cal-Sil. The licensee also adopted the 2D ZOI for Transco. For Kaowool, generic fiberglass, asbestos, Unibestos, and Kaylo insulations, the licensee assumed a conservatively large 28.6D ZOI. The NRC staff found that the ZOI radii are all technically adequate.

In some cases, the walkdown could not determine whether an insulation material was Temp-Mat™ or Kaowool. For these cases, the licensee assumed a 28.6D ZOI and 100 percent fines. In some other cases, the walkdown could not determine whether an insulation material was Nukon® or Temp-Mat™, for which the licensee assumed the 60 percent/40 percent size distribution applied to Nukon® and Temp-Mat™ but did not state which ZOI was applied. For coatings, the licensee evaluated both the 10D and 5D ZOI and then used the 10D ZOI debris load for the base case head loss.

The licensee conservatively enhanced the actual walkdown assessment for latent debris to 400 pound-mass (lbm) resulting in 60 lbm (25 cubic feet (ft^3)) of latent fibers. The walkdown assessment for the miscellaneous foreign debris was 106 ft^2 but the foreign debris estimated to accumulate on the strainer was increased to a sacrificial area of 178 ft^2. The chemical effects precipitates were included in the prototypes head loss testing where the surrogate precipitates were prepared based WCAP-16530-NP and WCAP-16785-NP, "Evaluation of Additional Inputs to the WCAP-16530-NP-A Chemical Model."

The licensee predicted the destruction of 14.2 ft^3 of main steam line unjacketed Cal-Sil outside any ZOI that was later determined to be jacketed and which will be removed from the resolution in a future revision. This quantity of Cal-Sil amounted to 7.4 percent of the total load of microporous debris. The licensee also assumed the destruction of 0.67 ft^3 of unjacketed fiberglass on a service water return line outside the ZOI, which is a relatively small quantity for this resolution.

The licensee assumed a two-category size distribution for debris, i.e., large pieces and small fines. The fibrous distribution, which was 40 percent large pieces and 60 percent small fines, was applied to the Nukon® and the Temp-Mat™ debris. The reflective metal insulation (RMI) distribution was 25 percent large pieces and 75 percent small fines. All other fibrous debris and microporous debris was assumed to be 100 percent small fines. The LOCA-generated coatings debris and the unqualified coatings debris were analytically treated as 10-micron particulate.

The licensee had some conservatisms in its debris generation/ZOI area as listed below:

- The walkdown assessed the latent debris at 202.5 lbm and assumed that 15 percent of this mass was fibrous debris. The licensee conservatively enhanced the actual walkdown assessment to 400 lbm resulting in 60 lbm (25 ft^3) of latent fibers.

- The walkdown assessment for the miscellaneous foreign debris was 106 ft^2 but the foreign debris estimated to accumulate on the strainer was increased to a sacrificial area of 178 ft^2.

- The LOCA-generated coatings debris and the unqualified coatings debris were analytically treated as 10-micron particulate.

NRC STAFF CONCLUSION:

For the debris generation/ZOI review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris generation/ZOI evaluation for Robinson is acceptable. The NRC staff considers this item closed for GL 2004-02.

5.0 DEBRIS CHARACTERISTICS

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

NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through December 17, 2008. The NRC staff found that the licensee generally provided the information requested in the content guide. No significant deficiencies or uncertainties were identified in the licensee's debris characteristics analysis based upon NRC staff's review. The licensee generally assumed conservative debris size distributions and physical properties that were consistent with approved guidance. The properties assumed for various debris types is summarized in Tables 1 and 2 below, copied from the licensee's supplemental submittal. The debris size distributions used by the licensee are consistent with the baseline guidance in Table 3-3 of the SE on NEI 04-07.

The NRC staff also found that the licensee's assumed debris properties for Robinson are generally consistent with Table 3-2 in NEI 04-07, with several minor exceptions. One exception is that the characteristic density used by the licensee for Cal-Sil, Kaylo, and asbestos/Cal-Sil is 18.6 lbm/ft^3, rather than the value of 14.5 lbm/ft^3 listed in NEI 04-07. The staff noted that the basis for this assumption is unclear, but it does not appear significant, and presumably should have been addressed when choosing and scaling the test quantity for the surrogate debris material used for representing this material in head loss testing. The Nukon® density of 175 lbm/ft^3 was taken from NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," dated October 1995,[22] rather than NEI 04-07. The staff considered this acceptable because 175 lbm/ft^3 was considered acceptable in this NRC-generated report. The source of the debris characteristics assumptions for Unibestos was not specified in the licensee's response. However, based upon a comparison to Table 3.2 in NEI 04-07, the NRC staff determined that they were based on the NEI 04-07 data for asbestos insulation.

Table 1: Licensee's Assumed Debris Size Distribution for Robinson

Debris	Initial Destruction Size Distributions
Unibestos	100% Fines
Cal-Sil/Asbestos	100% Fines
Cal-Sil	100% Fines
Kaylo	100% Fines
Nukon®	60% Fines / 40% Large Pieces

[22] ML083290498

Temp-Mat™	60% Fines / 40% Large Pieces
Nukon® or Temp-Mat™	60% Fines / 40% Large Pieces
Temp-Mat™ or Kaowool	100% Fines
Fiberglass (low density fiberglass [LDFG])	100% Fines
Unjacketed Insulation	100% Fines
RMI	75% Fines / 25% Large Pieces

Table 2: Licensee's Assumed Debris Properties for Robinson

Debris Material	Macroscopic Density (lbs./ft^3)	Microscopic Density (lbs./ft^3)	Characteristic Size (μm)
Nukon® Fiber	2.4	175	7*
Temp-Mat™	11.8	162	9*
Cal-Sil, Kaylo, and Asbestos/Cal-Sil	18.6	144	5**
Unibestos	10.0	153	2*
Latent Debris (Dirt/Dust)	N/A	169	17.3**
Latent Debris (Fiber)	2.4	175	7*

* - fiber diameter
** - spherical particle diameter

Per the NRC staff's SE on NEI 04-07, the licensee assumed that the following debris sources would become 100 percent small fines (generally due to a lack of available destruction data): Unibestos, Cal-Sil, Cal-Sil/Asbestos, Kaylo, Temp-Mat™ or Kaowool, generic fiberglass, and unjacketed insulation. In reality, NRC staff would expect that some fraction of debris generated from these materials would be destroyed into larger pieces that are less transportable and less problematic with respect to sump strainer blockage.

NRC STAFF CONCLUSION:

For the debris characteristics review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris characteristics evaluation for Robinson is acceptable. The NRC staff considers this item closed for GL 2004-02.

6.0 LATENT DEBRIS

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris (e.g., miscellaneous fiber, dust, dirt) existing within the containment and its potential impact on sump screen head loss.

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through December 17, 2008. The licensee presented a summary of its latent debris and screen sacrificial area analysis. An overview of the methodology that was used was presented, including its assumptions and the basic results. The licensee computed 202.5 lbm of latent debris based upon sampling and extrapolation. However, the licensee used 400 lbm as a conservative bound to the measured value. The licensee computed 106 ft^2 of sacrificial area and used 178 ft^2 for screen design. The NRC staff found that the methodology is acceptable, and the result is likely conservative.

The licensee used the default vertical surface debris inventory of 30 lbs., as recommended by the NRC SE. The latent debris on horizontal surfaces was estimated by a sampling methodology implemented during a plant walkdown using masolin cloths and swipes to collect debris for weight measurement. The weight per unit area was calculated, and the total weight of debris was obtained by scaling to the estimated surface areas of containment. A total of 34 locations were sampled. One hundred percent of the available horizontal area that was identified was assumed susceptible to debris accumulation.

The licensee used estimates of 15 percent for fiber and 85 percent for particulate, as allowed by the NRC SE. The licensee used an estimate of 400 lbm for the total mass of latent fiber and particulate. A licensee walkdown of containment provided an estimate of the surface area of tags and labels. A new licensee procedure requires new tags in containment to be made of stainless steel or ceramic-clad steel. These were not included in the estimate. The NRC staff found that this was reasonable since tags of such materials would be too heavy to be transported to the strainer. A licensee walkdown of containment provided an estimate of the surface area of plastic labels, tags, Mylar stickers, and cable ties. With added margin, the labels and tags totaled 15 ft^2 and, allowing for overlap, the potentially blocked area was taken as 15 ft^2. The area of cable ties totaled 91 ft^2, with 15 percent margin and also allowing for overlap. The total sacrificial area totaled 106 ft^2, and the screen design uses 178 ft^2. The licensee used an estimate of 400 lbm for the total mass of latent fiber and particulate, 100 percent of the available horizontal area that was identified was assumed susceptible to debris accumulation.

NRC STAFF CONCLUSION:

For the latent debris review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the latent debris evaluation for Robinson is acceptable. The NRC staff considers this item closed for GL 2004-02.

7.0 DEBRIS TRANSPORT

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through October 8, 2010. The licensee provided the information requested in the content guide. The licensee generally assumed conservative transport fractions that were based on approved guidance. In particular, the licensee's transport analysis generally followed the baseline methodology in NEI 04-07, and computational fluid dynamics was not used to determine containment pool flows. The licensee appears to have made several unsupported assumptions in the transport analysis that have a non-conservative effect, as described below.

The NRC staff requested RAIs on July 25, 2008 and December 3, 2009 regarding debris transport. The licensee provided responses in its letters dated December 17, 2008, March 30, 2010, and October 8, 2010. Following is a summary of the RAIs.

The NRC staff requested in RAI 1 on July 25, 2008, that the licensee justify the assumption that 50 percent of small fines of fiber and 50 percent of fine particulate would be retained in the upper containment rather than washed down to the containment pool. The licensee responded that the significance of this item was reduced due to the assumption of only 10 percent of debris being blown to the upper containment and other conservatisms associated with debris capture in inactive holdup volumes. The licensee's response further stated that explicit consideration of the debris that was retained in upper containment would only result in a head loss increase of approximately 0.08 ft. Although the NRC staff recognized some of the licensee's qualitative arguments, the NRC staff did not consider the licensee's assumption that only 10 percent of these types of debris would be blown into upper containment as a conservatism that could address the issue with upstream retention, since the assumption of 90 percent blowdown transport to the containment pool likely led to an overestimation of the capture of this debris in inactive containment pool volumes. RAI 4 of the July 25, 2008 request further stated the NRC staff's view that it appeared unrealistic to assume that multiple levels of grating would be capable of ensuring that only 10 percent of fine fiber and particulate would reach upper containment. The NRC staff also does not understand the basis for the licensee's predicted incremental head loss increase and expects that the incremental increase associated with this retained debris could be greater than predicted and could potentially challenge the NPSH margin for the plant. The licensee's response did not address these issues.

The NRC staff requested in RAI 2 on July 25, 2008, that the licensee justify the assumptions of zero percent erosion and zero percent transport for large pieces of fibrous debris. The licensee responded that the neglect of erosion was consistent with the baseline debris transport guidance and that a qualitative evaluation of the transport of large fibrous debris had been performed. The NRC staff did not consider this response to be acceptable for the following reasons: (1) the licensee took credit for refinements in the transport analysis that did not conform to the baseline guidance (e.g., credit for small and fine debris retention in upper containment); and (2) the qualitative assessment of large debris piece transport did not appear to be sufficiently rigorous. In particular, based on the licensee’s discussion, the NRC staff expects that some large-piece transport may occur at Robinson, were a more detailed evaluation of the containment pool flows to be performed.

The NRC staff requested in RAI 3 on July 25, 2008, that the licensee provide justification to support the assumption that 15 percent of the debris in the containment pool during pool fill up will be trapped in inactive pool volumes. The NRC staff’s SE on NEI 04-07 considers 15 percent to be the recommended maximum limit that licensees should assume for debris trapped in inactive volumes, but the NRC staff intended that this reduction in debris reaching the strainer should only be taken if an adequate technical basis exists to support it. No such basis was provided in the supplemental response. The licensee responded with the requested information, which showed that the inactive volumes exceed 15 percent of the total containment pool volume. Therefore, the NRC staff considered this item closed.

On December 3, 2009, the NRC staff requested in RAIs 1 and 4 that the licensee justify the credit taken for the retention of small fibrous fines and particulate debris in the upper containment and inactive holdup volumes or provide additional basis to demonstrate that the head loss impact of the debris is insignificant. Based on discussions during an April 22, 2010, teleconference, the licensee confirmed that 100 percent washdown of small fines is the applicable assumption for Robinson. The licensee clarified that 100 percent washdown is applied, not only to fines, but to small fines in its supplemental letter dated October 8, 2010. Therefore, the NRC staff considers this RAI to be resolved. In its supplemental information for

RAIs 1 and 4 dated October 8, 2010, the licensee stated that the debris quantity and characteristics for blowdown and washdown transport were recalculated based on the baseline methodology, as described in NEI 04-07. The licensee also stated that small fibrous fines and fine particulate were distributed with 25 percent to upper containment, 75 percent to lower containment, and 100 percent washdown of all small fines in upper containment. The licensee stated that the head loss testing was repeated using the revised debris quantity.

The NRC staff requested in RAI 2 on December 3, 2009, that the licensee justify the assumptions of zero percent erosion and zero percent transport of large pieces of fibrous debris. In its response, the licensee stated that it plans to address large pieces by assuming zero percent transport but 10 percent erosion of settled large pieces. These eroded fibers will be treated as fines in planned head loss testing. The NRC staff reviewed the licensee's response and found that although the licensee did not explicitly evaluate the transport of large pieces, the NRC staff recognizes that large pieces require significant pool velocities to transport. Furthermore, they are prone to being trapped on obstacles, and would not be able to climb onto the strainer surfaces that are raised above the floor level. The staff noted that Robinson has floor-mounted strainers that are slightly raised above the floor level and spread over a significant portion of the floor area.

In its supplemental information for RAI 2 dated October 8, 2010, the licensee stated that transport of large pieces was addressed by assuming erosion of the large pieces and including the erosion fines in the head loss test debris mix. Ten percent of the large pieces were assumed to erode and deposit on the screens as fines. This percentage was based on testing performed with small pieces of fiberglass and is therefore conservative based on surface area-to-volume considerations. As a result, the NRC staff accepted the licensee's arguments that large pieces will not significantly transport to and obstruct strainer surfaces and considers the 10 percent erosion of these pieces to be an acceptable approach.

<u>NRC STAFF CONCLUSION</u>:

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the debris transport has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris transport evaluation for Robinson is acceptable. Therefore, the NRC staff considers this area closed for GL 2004-02.

8.0 HEAD LOSS AND VORTEXING

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

<u>NRC STAFF REVIEW</u>:

The NRC staff review is based on documentation provided by the licensee through October 8, 2010. The licensee's approach to reducing strainer head loss was to install a relatively large strainer (> 4000 ft^2). Robinson contains significant amounts of various types of insulation materials within the predicted ZOIs. The licensee selected Enercon Top-Hat strainers and tested them at the Alion Science and Technology (Alion) test facility to show that head losses due to a combined chemical and non-chemical debris loads would not exceed the available NPSH margin for the residual heat removal (RHR) pumps, which are the only pumps to take suction through the strainer. Testing and evaluation found that the plant has only 0.1 ft of NPSH margin after fibrous, particulate, and chemical debris are accounted for.

There were numerous RAIs regarding head loss and vortexing during the review. The more significant RAIs are evaluated here.

The NRC staff requested in RAI 5 on July 25, 2008, that the licensee provide information regarding the size distribution of debris that was used in the head loss testing and a comparison of that sizing with the size of debris predicted to reach the strainer by the transport evaluation. The NRC staff requested in RAI 7 on July 25, 2008, that the licensee provide information regarding debris introduction techniques to justify that neither excessive agglomeration of debris nor non-prototypical debris deposition on the strainer occurred. The NRC staff requested in RAI 8 on July 25, 2008, that the licensee provide information on the types and amounts of debris that settled during testing. The NRC staff requested in RAI 11 on July 25, 2008, that the licensee provide the size distribution of the particulate insulation surrogate used during head loss testing. To ensure that these issues are addressed, the licensee stated that they planned to perform additional head loss testing that will incorporate "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing," dated March 2008,[23] for strainer head loss testing. The licensee further stated that the debris preparation and introduction for the testing will be consistent with methods determined to be appropriate for this type of testing and that the debris surrogate characteristics for the testing will be appropriate for this type of testing as described in the guidance. The updated testing will be used as a basis to re-evaluate the Robinson strainer performance.

The NRC staff requested in RAI 10 on July 25, 2008, that the licensee provide information regarding the testing that was conducted to justify that vortex formation would not occur under postulated accident conditions. In its response, the licensee provided additional information that discussed the testing and evaluations conducted to evaluate the potential for vortex formation for the Robinson strainers. The licensee stated that testing was conducted to determine a maximum approach velocity below which vortex formation would not occur at the minimum strainer submergence. The licensee identified that under clean strainer conditions that the flow rates through some of the top hat modules, close to the pump suction, could result in vortex formation. The licensee performed additional testing with vortex suppressors installed over the strainers and validated that even under the limiting clean strainer conditions, with the suppressors installed, that there was margin approximately 5 times the expected approach velocity. The licensee did not install vortex suppressors over all of the strainers but did so over all of the top hats outside the crane wall and the 8 sets of strainers closest to the pump suction inside the crane wall. The testing predicted that only the first two sets of strainers inside the crane wall could incur vortex formation under clean strainer conditions.

The licensee stated that the 8th set of strainers has an approach velocity that is 2.8 times lower than that predicted to result in vortex formation. Under fully loaded conditions, the testing showed that vortex formation would not occur at any of the strainer modules, even if no vortex suppressors were installed. The NRC staff reviewed the licensee's response and found that the licensee has evaluated the potential for vortex formation and installed modifications that protect against vortex formation in a conservative manner. The vortex suppressors that were installed provide significant margins to vortex formation even for the modules with the highest flow rates. The strainer modules that do not have vortex breakers installed also retain significant margin to vortex formation. Based on the significant margins demonstrated by the licensee, the NRC staff accepted the response to RAI 10.

[23] ML080230038

The NRC staff requested in RAI 14 on July 25, 2008, that the licensee justify that the head loss, determined during strainer testing, was not limited due to bed shifting, or to provide justification that if bed shifting did occur that it was prototypical of what would occur in the plant. The intent of the RAI was to ensure that any credited temperature correction of test results to higher sump coolant temperatures based on a viscosity correlation were justified. In its response, the licensee stated that it would perform additional head loss testing that will incorporate staff guidance for strainer head loss testing. The licensee stated that adequate NPSH margin is available at Robinson such that it is unlikely that the test results will have to be temperature corrected. The licensee also stated that the evaluation methodology would likely have to credit delayed onset of chemical effects. The original evaluation assumed that chemical precipitates were present with the full debris bed at the onset of recirculation.

In its supplemental information dated October 8, 2010, the licensee provided a summary of the testing and results. The licensee stated that the three tests, conducted in May 2010, exhibited relatively large increases in head loss with the initial chemical precipitate addition and very minor or no effect on head loss from the following chemical precipitate additions. The licensee stated that this pattern correlates to a saturation limit of chemicals in the debris bed and would limit the head loss effect of any increased chemical debris additions. The licensee further stated that to address the potential for bed shifting, the chemical effects head loss (tested at 86 degrees Fahrenheit (°F)) was not temperature corrected. The NPSH margin is determined based on chemical precipitate formation at sump fluid temperatures below 140 °F based on bench top test results, as previously described in the December 17, 2008, RAI response letter. The limiting NPSH values are tabulated in the response to RAI 16 below regarding NPSH limits. The NRC staff reviewed the results and found them acceptable. The NRC staff also reviewed the methodology used by the licensee in its final testing and found it to be per staff guidance.

NRC STAFF CONCLUSION:

For the head loss and vortexing area, the licensee has provided information such that the NRC staff has reasonable assurance that the strainer head loss and potential for air ingestion has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the head loss and vortexing evaluation for Robinson is acceptable. The NRC staff considers this area closed for GL 2004-02.

9.0 NET POSITIVE SUCTION HEAD

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through December 17, 2008. The NRC stated that the NPSH area for this plant contains less conservatism than the typical plant, based on the fact that the licensee can only ensure adequate NPSH margin post-LOCA for single-train RHR operation. Most other plants have sufficient NPSH margin, not only for two RHR pumps drawing from the sump, but also for two spray pumps taking suction from the sump.

The NRC staff noted that on the other hand, the licensee’s response to the RAIs included a discussion of the margin associated with dry air partial pressure. This approach was discussed by NEI at a public meeting. The licensee stated that over 26 ft of margin would be available from dry air partial pressure. The NRC staff noted that the 26 ft of margin and the methodology used to derive it are only valid once thermal equilibrium exists between the sump fluid and the containment atmosphere. This condition may not exist for a number of hours after the event. As a result, without detailed transient calculations, it is difficult to ascertain how much margin the licensee truly has available, particularly in the first several hours after the event when margins are typically at a minimum. Furthermore, the NRC staff noted that although the dry air pressure seems to indicate that there is a huge margin to failure (in terms of NPSH) it should be noted that the strainer structural limit may be more limiting. Although the limiting structural differential pressure was calculated with 60 °F as the fluid temperature and is conservative, the available margin was only 0.3 pounds per square inch (0.7 ft). The NRC staff concluded that the conservatism claimed was not as significant as presented when all aspects of strainer operation were considered.

The NRC staff requested in RAI 15 on July 25, 2008, that the licensee provide a description of the system configuration and assumptions that provide the basis for the flow rate (3,820 gallons per minute (gpm)) used to compute the "minimum NPSH margin" in the limiting NPSH margins calculation, including an explanation of which pumps are running and their flow rates. In its response, the licensee stated that 3,820 gpm is the flow rate at the beginning of recirculation. A single pump is aligned to the sump at 27 percent refueling water storage tank (RWST) level. The licensee stated the flow will be slightly lower when head loss across the screen is taken into account. The NRC staff stated that the licensee provided adequate information in response to the question and considered this item closed. The NRC staff noted that the licensee actually did, however, credit this flow reduction for reducing NPSH required in response to the question discussed below, increasing the NPSH margin from 0.1 ft to 0.3 ft.

The NRC staff noted that a single-train sump design flow rate of 3,820 gpm was used in the NPSH and head loss calculations as the flow rate that would result in the most limiting NPSH margin. The NRC staff requested the licensee to identify the maximum sump flow rate for dual-train operation and provide a basis that 3,820 gpm is the bounding flow rate when both NPSH and debris bed head loss are considered. In its response, the licensee stated that procedures limit operators to single-train RHR pump operation post-LOCA. In recirculation mode, the spray and safety injection (SI) pumps can be operated in piggyback alignment with only one RHR pump taking suction from the sump. The licensee stated that cold-leg injection flow can be limited by throttling the RHR heat exchanger outlet valves. The NRC staff reviewed this response and considered it reasonable. The staff stated that the plant design is for a single RHR pump to be transferred to recirculation mode. The licensee confirmed that plant procedures limit operators to the use of a single RHR pump. The staff noted that the licensee provided assurance that the limiting sump flow has been considered and considered this issue closed.

The NRC staff requested in RAI 16 on July 25, 2008, that the licensee address the potential for a single failure of a RHR throttle valve failure to close resulting in increased flow and the effect of this on NPSH margin or strainer structural limits. In its supplemental information dated October 8, 2010, the licensee stated that the throttle valves only require throttling if two RHR pumps are operating and providing suction to the high head safety injection pumps for simultaneous hot and cold leg injection. The licensee stated that this is not the limiting condition, because with two pumps operating, each pump flow rate is lower and the required NPSH is lower than in the single pump case. The licensee provided a table that illustrated the cases and NPSH margins associated with each. The licensee stated that it was determined that if simultaneous hot and cold leg injection was implemented with the sump temperature below 140°F that the strainer structural limit could be exceeded. The licensee stated that a procedure change would be made to prevent the structural limit from being exceeded. The issue was entered into the licensee's corrective action program to track the procedure change. Other potential flow conditions did not result in negative NPSH or structural margins. Therefore, the response to the RAI is adequate.

NRC STAFF CONCLUSION:

For the NPSH area, the licensee has provided information such that the NRC staff has reasonable assurance that it has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the NPSH evaluation for Robinson is acceptable. The NRC staff considers this area closed for GL 2004-02.

10.0 COATINGS EVALUATION

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through December 17, 2008. The guidance documents used for the review include the "Revised Guidance Regarding Coatings Zone of Influence for Review of Final Licensee Responses to Generic Letter 2004-02"[24] and Regulatory Guide 1.82.

For head loss testing, a 10D ZOI was used to calculate the quantity of coatings debris generated. The 10D ZOI is based on the staff position described in the NRC SE of NEI 04-07. As a parametric study, the licensee also analyzed a 5D ZOI for debris generation and transport analysis. The analysis of a 5D ZOI was not utilized by the licensee when determining the debris quantities for head loss testing, however it does demonstrate the conservatism of using a 10D ZOI.

Coatings in the ZOI and all unqualified coatings in containment failed as fine particulate. Debris transport analysis assumed that 100 percent of the coating debris particulate would transport to the sump. All head loss tests were conducted with particulate surrogates for coating debris. The NRC staff found that the surrogate material used for testing is acceptable.

Monitoring of containment coatings is conducted, at a minimum, once each fuel cycle. Monitoring involves conducting a general visual examination of accessible coated surfaces within the containment, followed by additional nondestructive and destructive examinations of degraded coating areas. The NRC staff finds that the licensee's coating assessment program is acceptable.

NRC STAFF CONCLUSION:

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or

[24] ML100960495

prototypically. Therefore, the NRC staff concludes that the coatings evaluation for Robinson is acceptable. The NRC staff considers this item closed for GL 2004-02.

11.0 DEBRIS SOURCE TERM

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through December 17, 2008. The NRC staff reviewed the licensee's housekeeping and foreign material exclusion programs and determined that they appear to adequately control their respective processes for maintenance of the debris source term as needed to maintain adequate ECCS strainer functionality.

The licensee has correctly identified and made improvements to the five categories of design and operational refinements associated with the debris source term considered in the sump performance analysis: (1) housekeeping and foreign material exclusion programs; (2) change-out of insulation; (3) modification of existing insulation; (4) modification of other equipment or systems; and (5) modification or improvement of coatings program.

The NRC staff noted that an on-going latent debris sampling program has not been established by the licensee for the containment, but there is substantial margin in the analysis of latent debris and the licensee has implemented programmatic controls to prevent a substantial increase in the latent debris in containment.

NRC STAFF CONCLUSION:

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris source term evaluation for Robinson is acceptable. The NRC staff considers this item closed for GL 2004-02.

12.0 SCREEN MODIFICATION PACKAGE

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through December 17, 2008. The licensee stated that it conducted the design and installation of the Robinson ECCS sump strainer modification under Engineering Change 63481. The replacement strainer consists of 128 high-performance top-hat-style assemblies, 88 located outside the crane wall and 40 located inside the crane wall, with a combined net effective surface area of approximately 4,200 ft^2. The assembly inside the crane wall is physically located almost entirely under the refueling canal. The licensee provided the following description of the strainer installation and plant modifications associated with the strainer replacement.

The strainer design incorporates two top hat lengths depending upon the available space. Each top hat is either 48 or 54 inches long with a square flange on one end. The high-performance top hat assemblies consist of four tubes (12-inch, 10-inch, 7-inch, and 5-inch diameter) fabricated from perforated plate. The annular space, where water flows horizontally through the top hats, contains a bypass eliminator material consisting of knitted wire mesh. The licensee stated that testing has shown that top hats with “debris bypass eliminators” minimize the quantity of bypassed fibrous debris. The top hat modules are bolted horizontally to the vertical sides of 15-in. square plenum boxes. In this design, water enters through the perforated plate surfaces of the strainers, travels through the debris bypass eliminators installed in the two annuli between the two outer cylinders and the two inner cylinders and flows through a plenum to a sump box covering the two existing ECCS suction inlet pipes located in the floor depression of the ECCS containment sump.

The licensee stated that to allow personnel access to the strainers, a personnel walkway, constructed of floor grating, is installed above the strainer plenum and top hats. The walkway floor grating is not expected to be submerged at the initiation of containment recirculation. Additional grating suspended from the personnel walkway support structure is expected to be submerged at the initiation of containment recirculation to act as a vortex suppressor. The personnel walkway and vortex suppressor are classified safety-related and Seismic Class I. For the strainer assembly that is inside the crane wall, grating is installed over the top hat assemblies to act as a vortex suppressor. The vortex suppressor is classified safety-related and Seismic Class I. There are no trash racks installed as they are not required for the new strainer design.

The licensee stated that interfering structures and components were modified, as required, to ensure that the replacement strainer could be installed and maintained. The portion of the chemical and volume control system excess letdown line that was routed through the existing ECCS sump and across the containment annulus between the crane wall and the containment wall on the east side of the refueling cavity was re-routed due to interferences with the new strainer. The interfering portion of the excess letdown line was moved higher up the crane wall so that the pipe and associated supports no longer interfere with the strainer. Also, three supports were redesigned or relocated. The coarse filtration screens located inside the crane square openings in the crane wall (approximately 2 ft across) were removed and replaced with a new structure constructed of stainless steel bars to prevent clogging with debris and to allow water to flow freely through the crane wall. The new structure is also designed to prevent personnel from using these openings to enter the High Radiation Areas inside the crane wall. The 4 ft 6 in. baffle wall surrounding the ECCS containment sump and the 9-in. curb surrounding the ECCS sump were modified for installation of the flow plenum.

<u>NRC STAFF CONCLUSION</u>:

For the screen modification package review area, the licensee provided information such that the NRC staff has confidence in the design of the strainer. Therefore, the NRC staff concludes that the screen modification package information provided for Robinson is acceptable. The NRC staff considers this item closed for GL 2004-02.

13.0 SUMP STRUCTURAL ANALYSIS

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

NRC STAFF REVIEW:

The NRC staff's review is based on Section 3k, Sump Structural Analysis, of the licensee's March 7, 2008 submittal, as well as additional information provided in RAI responses submitted on December 17, 2008 and March 30, 2010.

The licensee performed dynamic analyses for the ECCS sump strainer plenum and sump box using the GTSTRUDL computer program. The licensee stated the sump strainer assembly and associated structures had been designed in accordance with the American Institute of Steel Construction (AISC) Manual of Steel Construction, 8th and 9th Editions. The licensee stated the dynamic analyses applied loading combinations of dead weight, seismic loads (including hydrodynamic effects), live loads, and differential pressure loads as applicable. The NRC staff noted that these loads are consistent with the licensee's current licensing basis and the guidance given in NEI 04-07.

The licensee stated that of the piping lines identified as having potential HELB loadings on the new strainer (approximately six lines total), only the 2-inch normal letdown line was determined to have close enough proximity to the new strainer assembly to warrant action. To mitigate this potential jet impingement load (a calculated magnitude of 6,443 lbs.), a protective shield was installed to encompass jets from two separate elbows in the line and limited pipe whip associated with the downstream elbow break. The licensee stated that additional missile protection measures were not required to mitigate potential missile impacts on the new strainers. The new strainers were determined to be protected from potential missiles by substantial concrete structures such as: the crane wall, outer containment wall, and refueling canal. Those portions of the new strainers which were not protected by the aforementioned structures were stated to be "…not in the direct line of sight of potential missile hazards." For these reasons, the licensee concluded that there were no adverse consequences which needed to be considered on the strainer due to the hazardous effects of missiles. The NRC noted that the physical location of the strainers, coupled with the installed protective shield, adequately protects the strainer from potential HELB loading and possible missiles. The licensee also stated a backflushing strategy was not used for qualification of the new sump. Therefore, reverse flow loading was not considered in the structural evaluation.

The licensee's March 7, 2008, submittal lacked a detailed, quantitative summary of the sump strainer structural analysis. The NRC staff requested in RAI 17 on July 25, 2008, that the licensee submit a summary of the structural analyses performed in support of structurally qualifying the replacement sump strainers at Robinson. As a part of this summary, the NRC staff requested the licensee to provide the design code(s) of reference, applicable loads and load combinations, strainer component material type(s), and a comparison of any applicable actual stresses, forces, and displacements, such that compliance could be demonstrated with the design code(s) of reference.

In its response, the licensee detailed the structural analyses methodologies used to demonstrate the structural qualification of the replacement sump strainer top hat structures, sump plenum modules, and the vortex suppression personnel walkway. The licensee also provided the results of these analyses with a comparison of the actual, calculated stresses and interactions ratios to the code-allowable values for the various components making up each of the aforementioned structures. The licensee's response to RAI 17 indicated that the various components, including structural members, welds, anchor bolts, and supports, which make up the replacement sump strainer top hat structures, sump plenum modules, and the vortex suppression personnel walkway, were analyzed for structural adequacy using a combination of hand calculations and finite element analysis performed with the GTSTRUDL computer code. These components were subjected to bounding loading combinations consisting of deadweight, design basis earthquake and safe shutdown earthquake loads (developed using response spectra curves which enveloped the Robinson licensing basis response spectra curves), differential pressure loads, live loads, and thermal loads. These loading combinations are consistent with the loading combinations found in Robinson's updated final safety analysis report (UFSAR) and the NRC staff approved guidance of NEI 04-07. The NRC staff considered the methodologies used by the licensee acceptable, based on the licensee's use of standard, widely-accepted structural analyses techniques, coupled with structural loading combinations which are consistent with the Robinson licensing basis and NRC staff approved guidance.

Based on the licensee's response and the NRC staff's review, the NRC staff finds the licensee's response to RAI 17 sufficient and acceptable. The licensee used widely accepted structural analysis methodologies coupled with applied loading combinations which are consistent with the licensee's current licensing basis and NRC approved guidance found in NEI 04-07. The results presented by the licensee demonstrated that the components making up the replacement strainer top hat structures, plenum modules, and walkway structures have sufficient margins. The licensee quantitatively confirmed that every component analyzed was within the design code allowable stress limits and/or had an acceptable interaction ratio less than 1.0. Therefore, the NRC staff finds the response to RAI 17 acceptable.

NRC STAFF CONCLUSION:

The NRC staff concludes that the licensee's structural analysis of the sump strainers is adequate because it was conducted in accordance with standard industry guidance and contains associated conservatisms. Reasonable assurance exists that the strainer assembly will remain structurally adequate under normal and abnormal loading conditions such that it will be able to perform its intended design functions. Therefore, the NRC staff concludes that the sump structural analysis for Robinson is acceptable. The NRC staff considers this item closed for GL 2004-02.

14.0 UPSTREAM EFFECTS

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

NRC STAFF REVIEW:

The NRC staff review is based upon documentation provided by the licensee through December 17, 2008. The NRC staff determined that the licensee effectively addressed the NRC SE, Section 7.2, which addresses upstream effects and requires that licensees estimate the potential for water inventory holdup. The post-LOCA containment water level calculation has been prepared to address inactive pools and the minimum containment flooding levels during small break and large break LOCAs. The containment was adequately evaluated for areas where there is draw-down of the containment water surface due to flow restrictions, velocity increases, or frictional head loss as water travels to the sump strainer. It was confirmed there are no choke points where the flow of water to the strainer cannot keep up with the suction demands of the sump.

The licensee determined that trash racks did not need to be installed around the floor drain near the excess letdown heat exchanger and the floor drain near the existing ECCS sump screen. These floor drains are credited for positive flow in the containment water level calculation. Also, the licensee stated that drains must be verified clear of obstructions prior to containment closeout. Therefore, it is highly unlikely these drains will become clogged with debris. Should the drains become clogged, they are part of a system of floor drains that will enable water to be diverted from these drain openings to other drain openings on the containment floor during containment flooding.

The licensee determined that trash racks did not need to be installed around the floor drains at the bottom depressions below the steam generator platforms. Due to the close proximity of these drains to the site of the postulated large break LOCA, it is judged that even if these drains were not to become clogged, the 3-inch drain could not keep up with the flow emitting from the RCS break. Therefore, the containment water level calculation assumes one floor drain cavity below the steam generator platform as a water holdup volume. The other two floor drains are expected to allow flow to the containment sump.

The licensee determined that a trash rack will not need to be installed around the three-inch refueling canal drain. The water level calculation does not credit drainage through the 3-inch refueling canal drain following a large break LOCA. Note: There is no potential for adverse effects of smaller debris downstream of the 3-inch refueling canal drain. The expanded mesh screen at the west side of the sump trench was modified for passage of the plenum while continuing to prevent unauthorized access to high radiation areas beneath the refueling canal outside the crane wall. The coarse filtration screens located inside the crane wall covering the square openings were removed and replaced with a new structure constructed of stainless steel bars that allows water to freely pass through the crane wall without becoming clogged with debris. The personnel barrier fences that prevent unauthorized access to the high radiation areas underneath the refueling canal, inside the crane wall were modified.

The NRC staff noted significant conservatisms in the licensee’s submittal, as described below.

1. The containment water level calculation includes an evaluation showing that clogging of the 3-inch drain line at the north end of the refueling canal does not adversely impact the ability to go into containment recirculation mode. The water hold up is included in the analysis.

2. The containment water level calculation assumes one floor drain cavity below the steam generator platform as a water holdup volume.

The NRC staff requested in RAI 22 on July 25, 2008, that the licensee provide additional information regarding the likelihood of blockage at the refueling canal drain and the potential adverse consequences of blockage at this drain. The licensee responded stating that as originally stated in the 2008 response, no credit was taken for the refueling canal drain for a LBLOCA, because there is no trash rack at that location. Containment water level used in the evaluation assumed blockage at the refueling canal drain. For a SBLOCA, no blockage of the drain was assumed based on the minimal debris generated during a SBLOCA and the restricted access from the pump bays to the upper level of containment. The minimum water level calculation does evaluate holdup in the canal due to the head required to drive flow from the refueling canal at a rate to match containment spray flow. The NRC staff agreed that blockage of the refueling canal drain line was assessed conservatively.

The NRC staff indicated in RAI 23 on July 25, 2008, that the supplemental response provided by the licensee did not consider trash racks necessary for floor drains at the depressions below the steam generator platforms and noted that 2 of the 3 drains are credited with passing flow post-LOCA. Given the proximity of these drains to the RCS and the apparent potential for debris to accumulate at these drains via blowdown and/or washdown, the basis for crediting flow through these drains was unclear to NRC staff. In its response, the licensee stated that the drain locations make it unlikely that all three drains would become clogged under a single break scenario. If the unlikely case that the three drains were to clog, an additional 200 ft^3 of water could be retained. Having the following correlation: 8,698.8 cubic feet/feet between volume and level, the additional retention would therefore lower the minimum water level by 0.02 feet. The licensee stated that the lower water level may delay initiation of recirculation by 24 seconds (secs.) as an additional 200 ft^3 is injected into containment. Even if recirculation were to start with the water level 0.02 feet lower, the difference is less than the minimum pump NPSH margin, so there would be no adverse effects on the pumps. The NRC staff agreed that blockage of these drains would have no significant impact on the strainer operation.

The NRC staff indicated in RAI 24 on July 25, 2008, that the supplemental response provided by the licensee stated that debris blockage would not occur at the 2 feet wide openings in the crane wall where steel bars have been installed in place of the previous coarse mesh screens. The licensee responded stating that the size of the openings (openings are large at 24 inches by 6 and 3/8 inches) and the existing number of them (17) make the existence of a chokepoint very unlikely. The NRC staff agreed that openings of the size documented would not cause blockage of flow to the strainer.

NRC STAFF CONCLUSION:

The NRC staff concludes that the licensee's upstream effects evaluation was performed in a manner consistent with the approved methodology. Based on the provided information, the NRC staff concludes that the licensee has adequately reviewed the flow paths leading to the emergency sump screen for choke points, has considered the entrapment of debris upstream of the sump screen with regard to the holdup of water, and has considered the effect of water holdup in containment. Therefore, the NRC staff finds the licensee's treatment of upstream effects to be acceptable.

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the upstream effects evaluation for Robinson is acceptable. The NRC staff considers this item closed for GL 2004-02.

15.0 DOWNSTREAM EFFECTS - COMPONENTS AND SYSTEMS

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through December 17, 2008. The licensee's GL 2004-02 supplemental response contains a summary description of the methods used by the licensee to evaluate the downstream effects of debris that bypass the ECCS sump strainers. The licensee generally followed the methods prescribed in WCAP-16406-P and the associated NRC SE. Based on these evaluations, the licensee concluded that the Robinson ECCS components will not be subjected to excessive wear or blockage. The applicable components, except the containment spray eductors, were evaluated for 30 days of continuous operation. The containment spray eductors were evaluated to be operable for more than 24 hours. The actual duration of containment spray operation is expected to be 11 hours.

However, in lieu of using the bypassed debris quantities recommended in the WCAP, the licensee calculated the expected quantity of bypass debris based on data specific to Robinson. The licensee departed from the methodology of WCAP-16406-P in the pump wear evaluation by calculating the size distribution of depletable and non-depletable coating particulates in lieu of using the size specified in WCAP-16406-P. The analysis used the Robinson specific containment pool approach velocities to determine the plant-specific depletable and non-depletable particle sizes. The analysis credited the low average approach velocity of 0.002 ft/sec at the screens for depletion of particulates at the screens. The licensee stated that, as the fluid enters the screens, it will slow to an average velocity of 0.002 ft/sec. Thus, over time, allowing some particles to sink at the screens. The licensee based this assertion on the velocity at the strainer (0.002 ft/sec) being 1/75th the 0.15 ft/sec. settling velocity of the 100 μm to 400 μm size paint chips cited in the WCAP. Adjusting for the velocity difference, the licensee concluded that coatings greater than 50 μm would tend to settle at the screens. The licensee recognized that some of the particles would pass through the screens and contribute to downstream wear, but the overall concentration would deplete, over time. The licensee selected a depletion coefficient based on the measured turbidity of the fluid downstream of the screens during prototypical head loss testing. The licensee stated that the coefficient was conservatively determined because it did not account for multiple manual agitations of the debris in the tank that slowed the overall depletion rate. The licensee stated that when hot leg injection begins at approximately 11 hours after recirculation, the flow rate will be reduced, and the approach velocity will be much less than 0.002 ft/sec. No credit is taken for the additional settling and depletion that would coincide with the lower flow.

The licensee stated that the evaluations confirm that there would be no significant air entrainment within the ECCS that would either impact ECCS pump operation or cause formation of air pockets in ECCS piping. The licensee stated that the evaluations of the downstream effects of debris ingestion on equipment, including valves, pumps, heat exchangers, orifices, spray nozzles, and instrumentation tubing, are based on WCAP-16406-P methodology. The effect of debris ingested through the containment sump strainers during recirculation mode of the ECCS and CSS include erosive wear, abrasion, and potential blockage of equipment and flow paths. The calculations assess wear induced changes in system or equipment operation and evaluate the degraded hydraulic performance of pumps due to internal wear. The licensee concluded that excessive wear or plugging of the system valves, pipes, orifices, nozzles, or heat exchangers is not expected. Also, excessive pump wear from free-flowing abrasive/erosive wear or asymmetric packing wear is not expected. The licensee noted that containment spray pump "B" had a seal with a graphite bushing and replaced it with a seal having a metallic bushing. The licensee also concluded that the consequences of pump seal leakage into the auxiliary building are not increased by the presence of debris in the fluid.

NRC STAFF CONCLUSION:

For the ex-vessel downstream effects review area, the licensee has provided sufficient information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the licensee's evaluation of this area is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02.

16.0 DOWNSTREAM EFFECTS - FUEL AND VESSEL

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through May 19, 2022. Robinson conducted plant-specific penetration testing in accordance with Alion test plan submitted on November 26, 2012.[25] Robinson completed prototypical bypass testing of its new sump strainers with debris bypass eliminators in 2013.

The test array and layout for the Alion test tank included four horizontal double-ring tophats with debris bypass eliminators. The tophats were installed horizontally. The licensee incrementally added prepared fiber until maximum fiber load was achieved to simulate the worst-case scenario for fiber bypass while preventing early bed formation. The licensee used 5-micron nominal microfiber filter bags downstream to capture bypass fiber. The licensee conducted the bypass test with an initial approach velocity equal to 1.5 x the design approach velocity and then reduced the flow to 1 x the design approach velocity once the debris bed was verified. The licensee stopped all pumps after approximately 11 hours and aligned the system to simulate piggyback mode for hot leg injection via an SI pump with flow re-established based on hot leg injection at 0.17 x design approach velocity.

The debris types represented in the testing included Nukon®, Temp-Mat™, Kaowool, unibestos, and low density fiber glass. The licensee used Nukon® as the surrogate debris for all fiber types in the test. For low density fibrous debris, the licensee determined the mass by multiplying the volume of fiber by the density and Nukon® (2.4 lb./ft^3) and for high-density debris, the licensee determined the mass by multiplying the volume of fiber by the density of Temp-Mat™ (11.8 lb./ft^3). Nukon® fines and smalls were created following NEI ZOI guidelines. The licensee assumed that 10 percent of the total volume of unibestos is in fibrous form (unibestos is the trade name for calcium-silicate material containing asbestos fibers). The licensee stated that based on Alion's experiences, Cal-Sil materials contain 0-4 percent fibrous component and therefore, the 10 percent assumptions is conservative.

The licensee provided plant-specific debris load and transport fraction inputs and scaled them for the test. The licensee determined the scaled mass by multiplying the calculated transported mass by the scaling factor (0.0303) which is equal to the ratio of the full scale/reduced scale strainer surface areas. The licensee determined the scaled volume of the debris bed by dividing

[25] ML12331A178

the scaled transport mass by the density of Nukon®. The licensee determined the bed thickness by dividing the scaled volume by the prototype strainer area (121.2 ft^2).

The licensee prepared Nukon® fiber in accordance with NEI ZOI Fibrous Debris Preparation Procedure. The tests used smalls and fines classifications of fibrous debris, where the fines were used to represent 100 percent of the latent debris source term for the test and all of this debris was assumed to transport to the strainer. The small fines were assumed to transport to the strainer as follows: 1) 17 percent fines and 38 percent smalls for destroyed Nukon® and Temp-Mat™ insulation, 2) 22 percent fines and 63 percent smalls for Kaowool and fiberglass, and 85 percent fines for unibestos debris.

The NRC staff requested on April 22, 2022, that the licensee provide additional information to clarify the debris amounts used in the testing. The NRC staff noted that the debris amounts used in the testing were not from the limiting fiber break as described in the licensee's earlier submittals. The NRC staff also did not understand how the transport fractions were calculated or how eroded fibrous debris was accounted for in the testing and calculations. In its submittal dated May 19, 2022, the licensee provided updated transport calculations that were based on the higher fiber break and included erosion of larger fiber pieces. The updated calculations resulted in a slight increase in the in-vessel fiber described below. The licensee stated that the theoretical bed thickness after all fiber additions was 0.582 inches. The licensee did not observe full screen coverage and the inner surface area of the tophats also had exposed screen area after all fiber additions.

The licensee stated that the bypass test report examined fiber bypass amounts from three difference scenarios (most conservative, less conservative, and least conservative), each of which the total bypass quantity, mass of bypassed fiber after the pump switchover, and bypass per unit area using a test array area of 121.24 ft^2 were calculated. The licensee stated that the most conservative scenario resulted in 80.87 grams of total measured mass of bypassed fiber out of a total 14.1 lb. of fiber loaded in the test tank, resulting in a bypass fraction of 0.01313, which was used to compute the downstream in-vessel effects. The licensee calculated the total mass of bypassed fiber for the total effective plant strainer screen area (4,178 ft^2) as 2,893.9 grams. Since Robinson has 157 fuel assemblies, this results in 18.43 grams per fuel assembly (g/FA). The NRC staff reviewed the licensee's calculations and finds that the penetration calculation and test methodology, and the methods to determine the quantity of fiber reaching the core are acceptable. The NRC staff had questions about the basis for the debris amounts used in the penetration testing as noted above.

Robinson is a Westinghouse 3-Loop PWR downflow barrel/baffle configuration with alternate flow path through the upper head spray nozzles. Robinson parameters are listed in Volume 6, Revision 1 Table RAI-6.4-3 of WCAP-17788-P. The smallest hole diameter is 0.25 inches with upper head spray nozzle flow area of 4.12 in^2 and upper downcomer flow area of 3,703.7 in^2. Robinson is a T-Hot plant which has smaller nozzle opening than a T-cold plant and will not provide as much bypass flow due to high resistance to flow as the T-cold design such that the upper head temperature is consistent with the hot side temperature. Robinson has 157 fuel assembles, AREVA type fuel, fuel assembly pitch of 8.466 in., and uses 15x15 fuel assemblies. The licensee stated that proprietary total in-vessel fibrous debris limit in Section 6.5 of WCAP-17788-P, Volume 1, Revision 1 applies to Robinson.

The licensee used the methodology in Volume 1, Section 6.0 of WCAP-17788, Revision 1 for hot-leg breaks and Volume 3 of WCAP-17788-NP, Revision 1 for cold-leg breaks. The licensee stated that the maximum amount of fiber calculated to potentially reach the reactor vessel for

Robinson is 20.37 g/FA, after accounting for the larger fiber break and erosion of larger fiber pieces in the pool. This value is less than the in-vessel fibrous debris limit in Section 6.5 of WCAP-17788-P, Volume 1, Revision 1. The licensee stated that the applicable core inlet fiber threshold for Robinson is in Table 6-5 for Framatome (Areva fuel) of WCAP-17788-P, Volume 1, Revision 1. The core inlet fiber amount for Robinson is 20.06 g/FA, which is less than the threshold amount from the WCAP. This value also accounts for the larger fiber source term from the larger fiber break and erosion of fiber in the pool. The licensee stated that the earliest possible sump switchover time is greater than 20 minutes and may take up to 41 minutes from initiation of the LOCA event. This time includes 21 minutes to achieve low level in the RWST plus a 20 minute time critical operator action allowed for operators to align the low head safety injection pumps to the ECCS sump and start the pumps.

The licensee stated that based on plant-specific information for plant buffer, sump pool pH, volume and temperature, and debris types and quantities, test group 45 from WCAP-17788, Revision 1, Volume 5 is representative of Robinson and the predicted chemical precipitation timing is 24 hours. The licensee provided a table summarizing the key chemical precipitation parameters and comparing them to test group 45.

The licensee stated that Robinson performs injection realignment to mitigate the potential for boric acid precipitation no later than 11 hours, which is the less than the 24 hour chemical precipitation time. The licensee stated that based on Table 6-1 of WCAP-17788-P, Volume 1, Revision 1, $t_{block,}$ which is the earliest time that complete fuel inlet blockage can occur while not compromising LTCC (WCAP-17788-P) nor inhibit long term core cooling for Robinson is 260 minutes, which is less than the earliest time of chemical precipitation of 24 hours. The licensee stated that Robinson's rated thermal power of 2,339 megawatt thermal (MWt) is less than the analyzed power of 2,951 MWt in Table 6-2 of WCAP-17788-P, Volume 4, Revision 1 and is therefore bounded by the WCAP alternate flowpath analysis. The licensee stated that Robinson's specific alternate flowpath resistance is less than the analyzed value in Table 6-2 of WCAP-17788-P, Volume 4, Revision 1 and is therefore bounded by the resistance applied to the alternate flowpath analysis.

The licensee stated that the alternate flowpath analysis analyzed a range of recirculation flow rates from 8 – 40 gallons per minute per fuel assembly (gpm/FA), as shown in Table 6-2 of WCAP-17788-P, Volume 4, Revision 1. Robinson's ECCS recirculation flow rate corresponding to the worst-case GSI-191 hot-leg break scenario is 24.65 gpm/FA, which is within the range of ECCS recirculation flow rates considered in the alternate flowpath analysis. The licensee stated that based on comparison of the key parameters used in the WCAP-17788 alternate flowpath analysis to Robinson parameters, Robinson is bounded by the key parameters and the WCAP methods and results are applicable to Robinson. The licensee used NRC accepted methods to evaluate the in-vessel effects of debris.

<u>NRC STAFF CONCLUSIONS</u>:

For the in-vessel downstream effects review area, the licensee has provided sufficient information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the licensee's evaluation of this area is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02.

17.0 CHEMICAL EFFECTS:

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through December 17, 2008, as well as the updated plant specific path and schedule for resolution of GL 2004-02 supplement. The reference documents used for this review include the NRC staff SE of WCAP-16530-NP-A and “NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant Specific Chemical Effects Evaluations,” dated March 2008.[26]
The licensee uses sodium hydroxide (NaOH) for post-LOCA pool pH control. The maximum pH of the initial containment spray was 12.2 while NaOH was added. The maximum pH of the sump pool after all NaOH was introduced was 9.4. The licensee replaced their original containment ECCS sump strainer with the Enercon top hat strainer design. The strainer surface area increased from approximately 116 ft^2 with a new sump strainer area of 4,178 ft^2.

The licensee’s plant specific debris generation and transportation analysis determined that the debris sources for Robinson included qualified and unqualified coatings, Unibestos, Cal-Sil/asbestos, Cal-Sil, Kaylo, Nukon®, Temp-Mat™, Kaowool, low density fiberglass, unjacketed insulation, reflective metal insulation and latent debris (dirt, dust, and fiber).

The licensee’s prototypical hydraulic strainer array testing was based on the species and quantities of chemical precipitates predictions using the WCAP-16530-NP-A methodology. The licensee used the following key assumptions during the calculation of chemical precipitates:

- Maximum pH profile for the sump (pH = 9.4) and the containment sprays (pH = 12.2) were based on plant pH transient calculations;
- 725 lb./376 ft^2 of submerged aluminum and 234 lb./638 ft^2 of un-submerged aluminum;
- Debris quantities in the pool based on calculations of debris generation;
- Exposed aluminum components that are not submerged are wetted by containment spray;
- Sump pool not mixed until two pool turnovers are completed;
- Maximum calculated recirculation pool volume used;
- Once the maximum sump pool pH values are reached, pH values do not decrease over time;
- The containment spray runs for 11 hours, after which it is secured;
- Silicate inhibition of aluminum corrosion was credited in the determination of chemical precipitate quantities as described in WCAP-16785-NP, and:

[26] ML080380214

  - The silicon threshold value, above which silicate inhibition will occur, was assumed to be 100 parts per million (ppm) rather than the inhibition threshold of 75 ppm in WCAP-16785-NP;

  - The aluminum release reduction factor for 50 to 75 ppm silicon was assumed to be two, based on aluminum release reported in WCAP-16785-NP;

  - The licensee did not credit any inhibition for un-submerged aluminum;

  - The licensee did not credit any silicon released due to fiberglass dissolution;

  - The licensee determined that the limiting debris quantity was approximately 40 percent of the design basis Cal-Sil debris load (i.e., when credit is taken for silicon inhibition, the chemical precipitate load is maximized when the Cal-Sil debris input is reduced to 40 percent of that predicted to reach the screens). The licensee noted that the actual quantity of Cal-Sil debris used to develop the tested debris bed was based on 100 percent of the quantity predicted to reach the screens;

- Credit taken for the solubility of aluminum oxyhydroxide in the determination of precipitate quantities as described in WCAP-16785-NP; and,

- No credit taken for alloy-specific aluminum corrosion rates (i.e., Alloy 3003, 5005, and 6061).

The licensee’s results of the WCAP-16530-NP-A chemical model with the plant specific inputs showed that the expected precipitate would be a maximum debris load of 1,475 lbs. sodium aluminum silicate.

The NRC staff accepted the WCAP-16530-NP-A approach for calculating the quantity of precipitate to add to strainer testing. Although, the NRC staff did not agree that the model predictions for relative amounts of aluminum oxyhydroxide and sodium aluminum silicate precipitate are accurate. The NRC staff concluded that the WCAP-16530-NP-A predicted amounts of precipitate are acceptable since the methodology assumes that all aluminum precipitate and small quantities of each precipitate are effective at producing significant head loss across a fiber bed.

Prototypical hydraulic strainer testing was performed by Alion in a test tank at their facility in Warrenville, Illinois. This testing used tap water maintained between 80 °F and 90 °F. With the recirculation pump running, a plant-specific debris mixture was added to the test tank. This mixture represented insulation debris, coatings debris, and latent debris. Spargers on the recirculation pump discharge, agitators, and manual stirring were used to ensure insulation was transported to the prototype screens. Following the debris addition, chemical precipitates were added to the tank in increments. Head loss was tested at chemical debris loads up to 1,500 lbs. (1,475 lbs. calculated design load) sodium aluminum silicate equivalent; the measured head loss was 10.1 ft of water at test conditions. When adjusted for accident conditions, the measured head loss was 3.51 ft of water.

The NRC staff noted in RAI 18 on July 25, 2008, that the licensee had taken credit for silica inhibition of aluminum corrosion. On page 77 of the March 7, 2008, submittal, the licensee stated that when credit is taken for silica inhibition, chemical precipitate load is maximized when calcium silicate debris input is reduced to 40 percent of that predicted to reach the screen. The NRC staff asked if there are plausible break locations with less than the 40 percent Cal-Sil debris that result in a greater chemical precipitate load than tested due to insufficient silica reaching the threshold silica concentration? If so, the licensee was requested to discuss why the actual debris tested resulted in a more conservative head loss test compared to an alternate test. The licensee provided a graph showing that the use of 40 percent Cal-Sil debris load was chosen for testing since this provides the peak amount of chemical precipitate in the analysis. The licensee's analysis assumes that breaks that produce less Cal-Sil result in less overall chemical precipitate, presumably from less formation of a sodium aluminum silicate precipitate. The licensee's analysis also assumes that breaks with a greater amount of Cal-Sil debris are sufficient to significantly reduce aluminum corrosion by silica inhibition. The licensee only takes credit for silicate inhibition of aluminum for the submerged aluminum. The larger surface area of aluminum above the flood plane does not include silicate inhibition. Although a 40 percent Cal-Sil load was assumed for the WCAP-16530-NP-A spreadsheet analysis to yield the maximum amount of chemical precipitate for testing, the actual non-chemical debris load included a 100 percent Cal-Sil debris load; since adding all the Cal-Sil during strainer testing is conservative. The NRC staff reviewed the response and found it acceptable since the licensee used the break characteristics that maximize the quantity of chemical precipitate.

The NRC staff requested in RAI 19 on July 25, 2008, that the licensee provide the amounts of time assumed to reach the 50 ppm silicon and 100 ppm silicon concentrations in the containment pool and the basis for these assumptions. In its response, the licensee indicated that for the break that produces the 40 percent design load of Cal-Sil debris, the silica in the pool reaches 50 ppm in less than 48 hrs. and 99 ppm in under 240 hours. The licensee based their analysis on Los Alamos National Laboratory testing, NUREG/CR-6914, "Integrated Chemical Effects Test Project" dated December 2006,[27] that evaluated Cal-Sil dissolution in buffered, simulated post-LOCA environments. The NRC staff found the licensee's response acceptable since the durations stated by the licensee (50 ppm in less than 48 hours and 99 ppm in under 240 hours) are reasonable and based on testing.

The NRC staff requested in RAI 20 on July 25, 2008, that the licensee provide details concerning how aluminum oxyhydroxide (AlOOH) solubility was credited during the chemical effects evaluation. Was the approximately 13 percent reduction in chemical debris load based on temperatures above 140 °F? Was additional precipitate added to the test loop at a point representing when the pool temperature reaches 140 °F? In its response, the licensee indicated that precipitate was not added to the test to account for AlOOH formation once the post-LOCA pool temperature reached 140 °F. The licensee originally intended to credit long-term solubility of AlOOH precipitate. The NRC staff, however, has not granted long-term solubility credit to licensees implementing the WCAP-16530-NP protocol since the staff relies on conservatism in the assumption that all dissolved aluminum precipitates to balance uncertainties in the chemical effects area. The licensee stated that due to an error in the original calculation for aluminum in containment, the actual credit for AlOOH solubility is insignificant. The total plant-specific chemical precipitate mass without AlOOH solubility is an additional 3 lbs. or 0.2 percent of the total plant chemical precipitate load (1,500 lbs.). This amount is scaled based on strainer area for testing. The NRC staff reviewed the licensee's response and stated that given the amount of chemical precipitate term used for testing, the NRC staff found the RAI response acceptable on the basis of the insignificant difference between the tested amount and the additional amount that would be tested without the credit.

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[27] ML071800321

The NRC staff requested in RAI 21 on July 25, 2008, that the licensee provide the basis for why the chemical effects evaluation remains conservative when crediting aluminum inhibition by silica and solubility. In its response, the licensee stated that it has taken some steps to reduce the WCAP-16530-NP base model precipitate load. The silica inhibition of aluminum corrosion was achieved by crediting only silica produced by Cal-Sil dissolution, not including silica leaching from fiberglass. The NRC staff found this is acceptable since silica leaching from fiberglass can be significantly reduced by the presence of dissolved aluminum in the post-LOCA pool. The NRC staff noted that silica leaching from fiberglass is included when calculating the total amount of sodium aluminum silicate precipitate. The NRC staff found this to be conservative. In addition, the licensee made a conservative assumption that (higher) silica concentrations were needed for aluminum inhibition than was shown in WCAP-16785. For example, the WCAP showed some reduction in corrosion of aluminum once a 50 ppm silica concentration was attained and the licensee credits no reduction in aluminum corrosion until a 75 ppm silica concentration.

The NRC staff accepted that the licensee did not add AlOOH to the test only because the difference in total precipitate added to the test would have been insignificant. The NRC staff does not permit credit for long-term solubility of AlOOH. The NRC staff judged that based on the quantity of precipitate used in testing and the head loss response of the later batches of precipitate, adding less than 0.50 percent additional precipitate to the test would not have made a significant difference in the results. The NRC staff noted that although the NRC staff does not permit long term credit for solubility, the NRC staff recognizes that aluminum solubility increases significantly with increasing pH. Therefore, plants with higher post-LOCA pool pH, such as Robinson (pH > 9), would have a greater amount of aluminum remaining in solution compared to a plant with near neutral pH.

The NRC staff evaluated the licensee's RAI responses and concluded that the March 7, 2008, chemical effects analysis provided by the licensee is acceptable. The chemical effects portion of the head loss testing is acceptable since the licensee followed the WCAP-16530-NP-A baseline methodology with the pre-mixed WCAP precipitate. This method has been previously approved by the NRC staff.

NRC STAFF CONCLUSION:

For the chemical effects review area, the licensee has provided sufficient information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the chemical effects evaluation for Robinson is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02.

18.0 LICENSING BASIS

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the changes associated with GL 2004-02. The UFSAR has been updated to show the modified sump configuration. The licensee stated that that the other licensing basis changes associated with ECCS and CSS analyses are incorporated into the plant licensing basis by their GL 2004-02 supplemental response dated March 7, 2008, and any other docketed correspondence associated with GL 2004-02. Also, a license amendment to change verbiage in the Technical Specifications to account for the new sump strainer design was approved by the NRC in License Amendment No. 213, dated April 4, 2007.[28] The licensee committed to change the UFSAR in accordance with 10 CFR 50.71(e) to reflect the changes to the plant in support of the resolution to GL 2004-02.

NRC STAFF CONCLUSION:

For this review area the licensee has provided information, such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Based on the licensee's commitment, the NRC has confidence that the licensee will affect the appropriate changes to the Robinson UFSAR, in accordance with 10 CFR 50.71(e), that will reflect the changes to the licensing basis as a result of corrective actions made to address GL 2004-02. Therefore, the NRC considers this item closed for GL 2004-02.

19.0 CONCLUSION

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

The stated purpose of GL 2004-02 was focused on demonstrating compliance with 10 CFR 50.46. Specifically, the GL requested addressees to perform an evaluation of the ECCS and CSS recirculation and, if necessary, take additional action to ensure system function in light of the potential for debris to adversely affect LTCC. The NRC staff finds that the information provided by the licensee demonstrates that debris will not inhibit the ECCS or CSS performance following a postulated LOCA. Therefore, the ability of the systems to perform their safety functions, to assure adequate LTCC following a DBA, as required by 10 CFR 50.46, has been demonstrated.

Therefore, the NRC staff finds that the licensee's responses to GL 2004-02 are adequate and considers GL 2004-02 closed for the H.B. Robinson Steam Electric Plant, Unit 2.

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Date: July 14, 2022

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SUBJECT: H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2 - CLOSEOUT OF GENERIC LETTER 2004-02, “POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS” (EPID L-2017-LRC-0000) DATED JULY 14, 2022

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