U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW

OF THE DOCUMENTATION PROVIDED BY

DUKE ENERGY CAROLINAS, LLC

FOR THE MCGUIRE NUCLEAR STATION, UNITS 1 AND 2

CONCERNING RESOLUTION OF GENERIC LETTER 2004-02

POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

1.0 INTRODUCTION

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 generated by 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 pressurized water reactors (PWRs) 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 jet emanating from the broken RCS pipe. This debris may transport, via flows coming from the RCS break or from the containment spray system (CSS), to the pool of water that collects at the bottom of containment following a LOCA. Once transported to the sump pool, the debris could be drawn towards the ECCS sump strainers, which are designed to prevent debris from entering the ECCS and the reactor core. If this debris were to clog the strainers and the reactor core, containment cooling could be lost and the potential for core damage and containment failure would exist.

It is also possible that some debris would bypass the sump strainer and lodge in the reactor core. This could result in reduce 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 the amount of debris generated by a high-energy line break (HELB) could be greater, the debris could be finer (and thus more easily transportable), and that certain combinations of debris (e.g., fibrous material plus particulate material) could result in a substantially greater head loss than an equivalent amount of either type of debris alone. These research findings prompted the U.S. Nuclear Regulatory Commission (NRC) 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 rule, which is deterministic, requires maintaining long-term core cooling after initiation of the ECCS. The objective of GSI-191 is to ensure that post accident debris blockage will not impede or prevent the 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, which 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,” dated June 9, 2003 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML031600259). The Office of Nuclear Reactor Regulation (NRR) requested and obtained the review and endorsement of the bulletin from the Committee to Review Generic Requirements (CRGR) (ADAMS Accession No. ML031210035). As a result of the emergent issues discussed in Bulletin 03-01, the NRC staff requested an expedited response from 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 the 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 (ADAMS Accession No. ML042360586), was the follow-on information request referenced in Bulletin 03-01. This document set the expectations for resolution of PWR sump performance issues identified in GSI-191, to ensure the reliability of the ECCS and CSS at PWRs. NRR requested and obtained the review and endorsement of the GL from the CRGR (ADAMS Accession No. ML040840034).

The 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 are requested to submit the information specified in this letter to the NRC. This request is based on the identified potential susceptibility of PWR recirculation sump screens to debris blockage during design basis accidents requiring recirculation operation of ECCS or CSS and on the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and CSS recirculation and containment drainage. The GL 2004-02 required addressees to provide the NRC a written response in accordance with 10 CFR 50.54(f).

By letter dated May 28, 2004 (ADAMS Accession No. ML041550279), the Nuclear Energy Institute (NEI) submitted a report describing a methodology for use by PWRs in the evaluation of containment sump performance. NEI requested that the NRC review the methodology. The methodology was intended to allow 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 (ADAMS Package Accession No. ML043280641), the NRC issued an evaluation of the NEI methodology. The NRC staff concluded that the methodology, as approved in accordance with the NRC staff safety evaluation (SE), provides an acceptable overall guidance methodology for the plant-specific evaluation of the ECCS or CSS sump performance following postulated design basis accidents.

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

- TR-WCAP-16406-P-A, “Evaluation of Downstream Sump Debris Effects in Support of GSI-191,” Revision 1 (nonpublic), to address the effects of debris on piping systems and components.

- TR-WCAP-16530-NP-A, “Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191,” issued March 2008 (ADAMS Accession No. ML081150379) was submitted by the PWROG to provide a consistent approach for plants to evaluate the chemical effects, which may occur post-accident in containment sump fluids. The NRC staff reviewed WCAP-16530 and issued an SE that concluded the WCAP, as modified by the NRC staff’s limitations and conditions (L&C), which provides an acceptable technical justification for the evaluation of plant specific chemical effects related to GSI-191.

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

The NRC staff reviewed the TRs and found them acceptable to use (as qualified by the L&C 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 evaluation of licensee’s 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 (ADAMS Accession No. ML071060091), the NRC issued the content guide describing the necessary information to be submitted to allow the NRC staff to verify that each 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 design basis accident. By letter dated November 21, 2007 (ADAMS Accession No. ML073110389), the NRC issued a revised content guide.

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

- Corrective Actions for GL 2004-02
- Break Selection
- Debris Characteristics
- Latent Debris
- Debris Transport
- Head Loss and Vortexting
- ECCS and CSS NPSH
- Containment Coatings Evaluation
- Debris Source Term
- Sump Screen Modification Package
- Sump Structural Analysis
- Upstream Effects
- Downstream Effects – Components and Systems
- Downstream Effects – Fuel and Vessel
- Chemical Effects
- Licensing Basis

Resolution of GSI-191 has been more difficult than anticipated. Based on the interactions with stakeholders and the results of the industry testing, the NRC staff in 2012 developed three options that will be effective ways 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 (ADAMS Accession No. ML121310648). The options are summarized as follows:

- 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 mitigative 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 TR WCAP for NRC review and approval (in-vessel only).

    - Option 2 Risk Informed: South Texas Project pilot 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 options are innovative and creative, as well as risk informed and safety conscious. The Commission issued a Staff Requirement Memorandum on December 14, 2012 (ADAMS Accession No. ML12349A378), approving all three options for closure of GSI-191.

By letter dated May 8, 2013 (ADAMS Accession No. ML13141A403), Duke Energy Carolinas, LLC (the licensee) stated that they will pursue Option 1 for the closure of GSI-191 and GL 2004-02 for the McGuire Nuclear Station, Units 1 and 2 (McGuire).

The following is a list of documentation provided by the licensee in response to GL 2004-02:

RESPONSES TO GL 2004-02		
DOCUMENT DATE	ACCESSION NUMBER	
March 1, 2005	ML050670465	
September 1, 2005	ML052500399	
1st NRC RAI February 9, 2006 Accession No. ML060370427		
Licensee Responses to RAIs		
February 28, 2008	ML080730131	
April 30, 2008	ML081280488	
2nd NRC RAI November 18, 2008 Accession No. ML083080350		
Licensee Response to RAIs		
September 30, 2010	ML102870100	
July 2, 2012	ML12200A021	
July 31, 2013	ML13231A113	

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. The RAI Nos. referenced in the following evaluations correspond to the NRC RAIs dated November 18, 2008.

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

The following is a list of corrective actions taken by the licensee at McGuire in support of the resolution of GL 2004-02:

- Evaluation using the guidance of NEI 04-07, completed by Enercon Services, Inc. COMPLETE.

- Downstream effects evaluation using the TR-WCAP-16406-P-A, Revision 1 methodology. Containment walkdowns using the guidance of NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," April 19, 2002 (ADAMS Accession No. ML021490212). COMPLETE.

- The modification process and the plant labeling process have been enhanced relative to GL 2004-02 controls. COMPLETE.

- Replacement of the Microtherm® insulation, previously installed on portions of the reactor vessel heads, with reflective metal insulation (RMI). COMPLETE.

- Installation of a new ECCS sump strainer in Units 1 and 2 (≈1700 square feet per unit). COMPLETE.

- Integrated Prototype Test (IPT)/chemical effects test. COMPLETE.

- The licensee submitted a license amendment request (LAR) dated May 28, 2010 (ADAMS Accession No. ML101600256), to the NRC for ECCS water management modifications. This LAR reduces the number of required ECCS trains from four to three (two trains of residual heat removal (RHR) and one of containment spray (CS), referred to as "three-train flow" throughout this submittal). The effect of these changes include revisions to post-accident response that reduce recirculation flow rates through the ECCS sump strainers, increases post-accident sump pool volume and decreases the predicted volume of transported sump pool debris. This license amendment was approved by the NRC on September 12, 2011 (ADAMS Accession No. ML11131A133), and the modifications are complete for McGuire. COMPLETE.

- ECCS sump strainer performance for McGuire was confirmed in 2011 by performing a prototype chemical precipitates head loss test. COMPLETE.

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.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through April 30, 2008.

The licensee originally indicated that a limiting break due to particulate debris generation could occur at a control rod drive mechanism (CRDM). The licensee has replaced the Microtherm insulation on the reactor vessel head with reflective metal insulation.

The licensee indicated that secondary line breaks would not introduce different debris types to the pool, would involve jets at lower pressure and, thus, would be bounded by primary line breaks and were not considered. The NRC staff review of the licensee's Updated Final Safety Analysis Report (UFSAR) contents makes no mention of recirculation being needed or assumed available for secondary (main steam or feedwater) line break accidents, so, consideration of those breaks would not be needed for evaluating sump strainer adequacy.

The licensee used a discrete approach to determine the break locations to analyze for debris generation rather than the NRC staff approved methodology contained in the NEI 04-07 guidance report and the associated NRC staff SE (GR/SE) suggested evaluation at 5-foot intervals along the primary coolant loop and other piping being evaluated for potential break locations. The licensee's original assumed zone of influence (ZOI) of 17 diameters (D) for jacketed Nukon, jacketed Thermal-Wrap, and jacketed Knauf insulation was large enough to encompass the entire steam generator (SG) compartments and the judgment based discrete approach was reasonable as nearly any break location in a piping run would affect nearly all the insulation in the SG compartment. However, the licensee refined the ZOI for these insulation types to 7D. The licensee stated in their supplemental response dated February 28, 2008, that review of the break locations determined, assuming a 17D ZOI for these insulation types shows the limiting break location ("B" loop hot leg) for debris generation remains bounding when the 7D ZOI is applied. The licensee's RAI response dated April 30, 2008, stated that the change from the 17D to 7D ZOI resulted in the limiting break remaining on the "B" loop hot leg. This might suggest that the licensee appropriately revisited the break location determination for the reduced ZOI and not just recalculated the debris totals for the break locations selected considering the larger 17D ZOI. However, it might also mean that debris generation was recalculated for the previously determined break locations and the limiting break location moved from one previously determined point to another based on those results.

RAI-4:

> Please state whether or not the break location selection was revisited when the ZOI for fibrous insulation was changed from 17D to 7D. If break selections were not revisited, please provide the rationale for not doing so. If the break selections were revisited, please provide the top four breaks in terms of debris generation for the 7D ZOI. (The supplemental response sent by letter dated February 28, 2008, indicates only that the break locations already identified for a 17D ZOI

were reassessed for debris quantity generation and confirmed not to have changed relative ranking.)

FINAL NRC STAFF REVIEW:

Based on the licensee's July 2, 2012, RAI responses.

Summary of RAI-4:

RAI-4 requested that the licensee state whether the break selection process was revisited following the decision to decrease the ZOI for fibrous insulation from 17D to 7D. This RAI is intended to ensure that the licensee used current information when performing the break selection evaluation.

RAI-4 Licensee Response Summary:

The licensee stated that they were no longer crediting the reduced ZOI for fibrous insulation and that the 17D ZOI had been incorporated into the debris generation evaluation. A significant amount of fibrous insulation on both McGuire units is being replaced with RMI. The fibrous insulation on the reactor coolant loop, reactor coolant pumps, and SGs is being replaced. The licensee stated that the break selection process was revisited considering the insulation configuration after replacement of the fibrous insulation with RMI to ensure that the limiting break was identified. The licensee stated that the post-modification break selection process followed guidance approved by the NRC.

RAI-4 Acceptability of Response and Basis:

The NRC staff considers the response to RAI-4 to be acceptable because the licensee used the current as-built insulation configuration and the NRC staff approved ZOI for fibrous insulation, as well as approved methodology, to determine the limiting break location.

FINAL NRC STAFF CONCLUSION:

The NRC staff had previously determined that the licensee had used approved methodology for conducting its break selection evaluation. Because the licensee had changed its ZOI size used to determine the amount of fibrous debris that could be generated by a break, the staff concluded that the limiting break location could change. The NRC staff requested clarification that the licensee had reperformed the break selection process using the approved ZOI. The licensee verified that the break selection evaluation considered the approved ZOI. Since the NRC staff found that the evaluation was redone using the approved ZOI and approved methodology, the staff concludes that the break selection evaluation for McGuire is acceptable. Based on the information provided by the licensee, the NRC staff considers this item closed for GL 2004-02.

4.0 DEBRIS GENERATION/ZONE OF INFLUENCE (EXCLUDING COATINGS)

INITIAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through April 30, 2008.

The McGuire debris generation evaluation followed approved guidance. Only RMI and low density fiberglass are predicted to be within the ZOI of postulated breaks. Microtherm insulation that was on the reactor heads was removed and replaced with RMI. The original ZOIs selected were 17D for fibrous insulation and 28.6D for RMI. The jacketed fibrous ZOI was later reduced to 7D based on insulation destruction testing conducted for other plants. The information provided by the licensee did not provide enough information to make it clear that the testing referenced to justify the reduced ZOI was applicable to the insulation system in use at McGuire. In addition, the submittal stated that the original debris size distribution was revised based on the reduced ZOI.

RAI-1:

> Please state whether the testing identified in the WCAP-16710-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and Nukon® Insulation for Wolf Creek and Callaway Nuclear Operating Plants," was specific to the McGuire Nuclear Station, Units 1 and 2, (McGuire) insulation systems. If not, please provide information that compares the McGuire encapsulation and jacketing systems structures with the systems that were used in the testing, showing that the testing conservatively or prototypically bounded potential damage to insulation materials.

RAI-2:

> Considering that the McGuire debris generation analysis diverged from the approved guidance contained in NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, please provide details on the testing conducted that justified the ZOI reductions for jacketed Nukon®. The information should include the jacket materials used in the testing, geometries and sizes of the targets and jet nozzle, and materials used for jackets installed in the plant. Please provide information that compares the mechanical configuration and sizes of the test targets and jets, and the potential targets and two-phase jets in the plant. Please provide an evaluation of how any differences in jet/target sizing and jet impingement angle affect the ability of the insulation system to resist damage from jet impingement. Please state whether the testing described in test report WCAP-16710-P was bounding for the McGuire insulation systems. If not, please provide information that compares the McGuire encapsulation and jacketing systems structure with the system that was used in the testing, showing that the testing conservatively or prototypically bounded potential damage to the insulation materials.

RAI-3:

Please clarify if unjacketed Nukon® is present in the McGuire containment and, if so, please state whether the 17D ZOI was used instead of the 7D ZOI. Please provide the resultant debris quantities for unjacketed Nukon®. (Section 3(b)(2) of the supplemental response sent by letter dated February 28, 2008, stated that unjacketed Nukon® was present within the evaluated ZOIs. The supplemental response further stated that test report WCAP-16710-P demonstrates a refined 7D ZOI for jacketed Nukon® insulation, but was silent with respect to how unjacketed Nukon® was handled with respect to ZOI reduction from 17D to 7D.)

RAI-5:

Provide information that compares the ability of the McGuire fibrous jacketing system and the test report WCAP-16710-p-tested jacketing system to resist steam jet damage. Please provide information that demonstrates that the McGuire jacketing is at least as structurally robust as the jacketing that was subjected to the test report WCAP-16710-P steam jet impingement testing.

RAI-6:

Please provide information that verifies that test report WCAP-16710-P testing used to justify a ZOI reduction from 17D to 7D for jacketed fiber insulation was conducted prototypically or conservatively. Include information on nozzle size, target size, and the various test configurations (jet to target distance and relative angle, location of jacket seams, etc.) conducted to show that the testing was prototypical or conservative.

RAI-7:

Please provide the fibrous size distribution (including debris amounts determined) for the debris generation calculation based on the 7D ZOI.

RAI-8:

Please provide details regarding the tags and labels equipment qualifications and engineering judgments used as basis for reduction of tag and label quantities which were originally assumed to fail and reach the sump. Provide the technical basis for the conclusion that tags and labels outside the crane wall in lower containment are capable of withstanding post-loss-of-coolant accident (post-LOCA) conditions. Justify the application of the Institute of Electrical and Electronics Engineers (IEEE) Standard 323-1974, "IEEE Standard for Qualifying Class 1 E Equipment for Nuclear Power Generating Stations," in qualifying Electromark® labels for a post-LOCA environment.

RAI 10:

Please provide the details of the methodology used for the tag and label refinement evaluation. Provide details of the equipment qualifications and engineering judgments used as basis for reduction of tag and label quantities which are assumed to fail and reach the sump.

FINAL NRC STAFF REVIEW:

Based on the licensee's July 2, 2012, RAI responses.

Summary of RAI-1:

RAI-1 requested that the licensee state whether industry debris generation testing referenced by McGuire in a previous submittal was conducted specifically on the applicable McGuire insulation systems, and if not, to provide justification that the testing was representative of the McGuire insulation system performance under jet impingement conditions.

RAI-1 Licensee Response Summary:

The licensee stated that the debris generation evaluation for McGuire is based on staff approved guidance for ZOIs and that the testing in question is no longer used as a basis for their debris generation evaluation. The licensee has reperformed the debris generation evaluation using NRC staff approved guidance. The licensee further stated that the removal of a significant amount of fibrous insulation from containment combined with the use of approved staff guidance for debris generation results in a significantly reduced potential fibrous debris load within the staff accepted 17D ZOIs.

RAI-1 Acceptability of Response and Basis:

The NRC staff finds the licensee response acceptable because the use of potentially nonconservative test results was abandoned and replaced with the use of NRC staff approved ZOI guidance.

Summary of RAI-2:

RAI-2 requested that the licensee provide details on the testing used to justify reductions in ZOI volumes at McGuire compared to those approved by the NRC staff.

RAI-2 Licensee Response Summary:

The licensee stated that the testing in question is no longer used as justification for reduced ZOI volumes and that NRC staff approved ZOI sizes were used to determine the debris generation values for McGuire.

RAI-2 Acceptability of Response and Basis:

The NRC staff finds the response to RAI-2 acceptable because the licensee decided that use of the smaller ZOI sizes based on industry testing would not be used and they reverted to NRC staff approved guidance for ZOI sizes.

Summary of RAI-3:

RAI-3 requested that the licensee state whether unjacketed Nukon is present in the McGuire containment and to provide the ZOI used in the debris generation evaluation. The RAI was intended to determine whether the licensee had treated jacketed and unjacketed Nukon differently by using different ZOIs based on whether metal jacketing was installed over the insulation blankets.

RAI-3 Licensee Response Summary:

The licensee stated there is unjacketed Nukon installed within the McGuire containments. However, as stated in the response to RAIs 1 and 2, the licensee reiterated that they are no longer crediting nonapproved ZOIs for fibrous insulation and that the ZOI for jacketed and unjacketed fibrous insulation is 17D.

RAI-3 Acceptability of Response and Basis:

The NRC staff finds the response to RAI-3 acceptable, because the licensee used NRC staff approved guidance for determining ZOI sizes.

Summary of RAI-5:

RAI-5 requested that the licensee provide additional information regarding the construction of the target insulation systems used in industry jet impingement testing and how the construction of these systems compares to the insulation systems installed at McGuire for which the industry testing was credited.

RAI-5 Licensee Response Summary:

The licensee stated that credit for smaller ZOIs based on industry testing was no longer credited for the McGuire debris generation evaluation. The McGuire debris generation evaluation was completed using the NRC staff accepted ZOI value of 17D for fibrous insulation.

RAI-5 Acceptability of Response and Basis:

Because the licensee used NRC staff approved guidance to determine the debris generation values in their final analysis, the NRC staff concluded that the information requested in the RAI was no longer required. Therefore, the response to RAI-5 is acceptable.

Summary of RAI-6:

RAI-6 requested that the licensee provide information to justify that the testing that was cited to justify a reduced ZOI for fibrous insulation was conducted realistically or conservatively with respect to several variables that should have been considered in the tests.

RAI-6 Licensee Response Summary:

The licensee stated that credit for smaller ZOIs based on industry testing was no longer credited for the McGuire debris generation evaluation.

<u>RAI-6 Acceptability of Response and Basis</u>:

Because the licensee no longer credited the testing, the NRC staff determined that a response to this RAI is not required. Therefore, the response to RAI-6 is acceptable.

<u>Summary of RAI-7</u>:

RAI-7 requested that the licensee provide the debris size distribution based on a 7D ZOI.

<u>RAI-7 Licensee Response Summary</u>:

The licensee stated that McGuire is no longer crediting the 7D ZOI, but has reverted to the NRC staff approved ZOI of 17D. The licensee also provided the size distribution used in the debris generation evaluation based on the 17D ZOI.

<u>RAI-7 Acceptability of Response and Basis</u>:

The size distribution used in the updated evaluation is consistent with NRC staff guidance. Therefore, the response to RAI-7 is acceptable.

<u>Summary of RAI-8</u>:

RAI-8 requested that the licensee provide details regarding the justification for a reduction in the quantities of tags and labels that were originally assumed to fail and reach the sump.

<u>RAI-8 Licensee Response Summary</u>:

The licensee stated that McGuire had previously provided the bases for their conclusions regarding the assessment of tags and labels. However, the licensee clarified the information in the response to RAI-8 and stated that a refinement had been made to the evaluation subsequent to the previous submittal. The licensee stated that it was assumed that metal tags hung with braided stainless steel connections would not fail, or would sink and not transport. The licensee stated that Electromark labels outside the crane wall in lower containment are assumed not to fail based on their proximity to postulated breaks, the containment geometry, and the environmental conditions anticipated in that location following a postulated LOCA. The licensee stated that no reduction for tags and labels was taken for those that are installed in the lower or upper plenum of the ice condenser even though it is expected that some of the tags and labels installed in the upper plenum would not fail or transport to the sump. The licensee also provided information regarding reductions in the amount of labels that could reach the sump from the pipe chase and upper containment. A reduction in the number of labels that could transport from the pipe chase was credited due to very low flow velocities in the room. A reduction in the number of labels that fall directly onto gratings was also credited because of the likelihood of these labels being captured on the grating. The licensee stated that all tags and labels that fall to the operating floor are assumed to reach the sump. The licensee stated that this is conservative because the curb around the refueling canal and the elevated canal drains would prevent many of the tags from transporting. The licensee provided details of the test program used to qualify the Electromark labels. The test program was conducted using IEEE standards as guidance.

RAI-8 Acceptability of Response and Basis:

The NRC staff reviewed the assumptions, testing, and bases used to determine the amount of labels and tags calculated to reach the strainer. The NRC staff agrees that metal tags will not reach the sump. Additionally, the testing used to qualify the Electromark labels was performed based on industry standard testing and is acceptable. The NRC staff considered tests that they had witnessed that studied the transport of tags and labels and determined that the assumptions regarding transport of these items credited by the licensee were conservative or reasonable. Therefore, the response to RAI-8 is acceptable.

Summary of RAI-10:

RAI-10 requested that the licensee provide details regarding the methodology used for the refinement of the tag and label evaluation.

RAI-10 Licensee Response Summary:

The licensee stated that the information requested in RAI-10 was included in the response to RAI-8.

RAI-10 Acceptability of Response and Basis:

The NRC staff accepted the response to RAI-8 and also concluded that it is applicable to RAI-10. Therefore, the licensee's response to RAI-10 is acceptable.

FINAL NRC STAFF CONCLUSION:

The NRC staff had previously determined that the licensee had used approved methodologies for conducting its debris generation evaluation with the exception of crediting ZOIs smaller than those approved by the staff. The licensee has changed its ZOI size used to determine the amount of fibrous debris that could be generated by a break to agree with NRC staff approved guidance. The licensee reevaluated the amount of debris that could be generated by a limiting break, using staff approved methodology, after modifications to significantly reduce the amount of fibrous insulation within the containments. The licensee also reevaluated the potential for tags and labels to transport to the sump. The NRC staff found the updated evaluation to be acceptable. Other aspects of the debris generation evaluation had previously been found to be acceptable by the NRC staff. Therefore, the staff concludes that the debris generation evaluation for McGuire 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 head loss.

INITIAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through April 30, 2008.

The assumption that large pieces are 6 inches in size, is inconsistent with the guidance that considers large pieces to be larger than 4 inches in size. This assumption is nonconservative. However, because large pieces are not too significant from a head loss standpoint, and considering that the licensee assumed small pieces are all 1-inch clumps likely results in a conservative evaluation of debris characteristics. The staff does not consider the licensee assumption concerning the size of large debris pieces to be a significant concern.

The licensee provided the information requested in the content guide. However, the information presented in the supplement appears to be associated with the 17D ZOI for fiberglass, which was used for the original nonchemical array testing that the licensee is no longer planning to credit. The licensee changed ZOI sizes for jacketed Nukon insulation as described in the debris generation section.

The licensee stated that the debris at McGuire includes fibrous insulation and RMI debris, failed coatings, and latent debris. For fibrous insulation (Nukon, Knauf, and Thermal-Wrap low-density fiberglass) the licensee provided debris size information consistent with the GR/SE baseline values of 60 percent small fines / 40 percent large pieces. This size distribution is clearly associated with the 17D ZOI and not the new 7D ZOI. No information was provided in the licensee's February 28, 2008, supplement on the debris characteristics assumed for the reduced size 7D ZOI. The licensee assumes a size distribution of 60 percent small pieces and 40 percent large pieces within a 7D ZOI for low-density fiberglass.

The RMI size distribution was based on the NRC SE approving NEI 04-07. This size distribution appears acceptable but is not expected to be important since RMI was not included in the head loss testing.

The density and characteristic size information provided for all debris is reasonable and consistent with guidance.

For foreign materials, the licensee conservatively assumed a fairly large quantity of debris. The assumption is 347.5 square feet. The licensee took 75 percent of this surface as sacrificial strainer area, which is consistent with NRC-approved SE guidance.

Coatings are reviewed separately.

<u>FINAL NRC STAFF REVIEW</u>:

The licensee revised its debris generation calculation to use methodology consistent with NRC staff accepted guidance.

For this review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. All aspects of the debris characteristics evaluation had previously been found to be acceptable by the NRC staff. Therefore, the NRC staff concludes that the debris characteristics evaluation for McGuire 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 existing within the containment and its potential impact on sump screen head loss.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through April 30, 2008.

The licensee presented a high-level summary of its latent debris and screen sacrificial area analysis. An overview of the methodology that was used is presented, a partial presentation of assumptions is provided and the basic results of the analysis are presented. In general, little in the way of details of the models, data and results are presented. The licensee provided estimates of the mass of latent fiber and particulate. The methodology used to estimate the quantity of the latent debris was not provided. The information provided was insufficient to judge the adequacy and conservatism of the evaluation.

McGuire containment foreign materials walkdowns were conducted using NEI 02-01 guidance for both units. As a part of these walkdowns, the existence of latent debris was evaluated. The walkdown results were tabulated using walkdown notes and photographs. Only materials that were expected to remain in containment after an outage were included in the inventories.

Subsequent to these walkdowns, a tag and label reduction evaluation was performed to analytically reduce the amount of stickers, labels, and tags that could fail in a postulated LOCA and transport to the ECCS sump pool, using current equipment qualifications and engineering judgment. An additional 20 percent was then added to take into account missed materials, areas of low photograph-to-area size ratios, and inaccessible areas due to limited space and high radiation. The latent debris tabulations were used to develop a reasonable but conservative total square footage of each material by containment area. Generic sampling data (mass densities) from other plants, combined with subjective walkdown observations as to plant cleanliness, were also used to make quantitative estimates of latent debris by containment area.

The total latent debris in McGuire were estimated to be 140 pounds mass (lbm) and 90 lbm, respectively. A bounding value of 200 pounds was used in the debris generation evaluation to provide adequate margin.

Per NEI 04-07, the fiber content of the latent dust and dirt debris is assumed to be 15 percent by mass. With the assumption of 200 pounds of latent debris, 30 pounds of the debris is considered to be latent fibers. The NRC SE for NEI 04-07 further assumes that the latent fiber bulk density is assumed to be the same as low density fiberglass material (2.4 pounds per cubic feet). This results in 12.5 cubic feet of latent fibrous debris. NEI 04-07 and the NRC SE, Method 2 provide a conservative estimate of the latent fibers and particulate densities (94 pounds per cubic feet and 169 lb/ft3, respectively). To be consistent for the McGuire head loss analysis, the microscopic density of the latent fiber material was assumed to be equivalent to Nukon® fiberglass (175 pounds per cubic feet). The latent particulate debris size was assumed to be 17.3 microns. The latent fiber was assumed to be for the same as commercial fiberglass (approximately 7 microns). These assumptions are consistent with staff guidance.

The following discussion provides the assumptions and their bases for the tag and label reduction evaluation in the McGuire containment buildings:

- All tag and label amounts are estimated from plant drawings, walkdowns, and walkdown photos. All amounts were initially estimated and then adjusted to provide conservatism; however, all are based on engineering judgment. The reductions will be applied to the actual tag or label counts and then rounded up to the nearest whole number (i.e., there are no partial tags or labels).

- A large portion of the tags and labels inside the crane wall in lower containment will be in the break's ZOI and will fail. It is not possible to conservatively estimate the percentage of tag and label surface area that is in the ZOI; therefore, all tags and labels inside the crane wall in lower containment will be assumed to fail.

- Plastic tags outside the ZOI are assumed to stay intact. While there may be some deformation due to the LOCA environment, they are assumed to not become overly pliable (i.e., they will not deform to pass through an obstruction that has a smaller dimension than the tag).

The miscellaneous latent debris total area contribution to sump strainer blockage at McGuire is 347.5 square feet, as shown in Table 3D3-2. The licensee used the NEI 04-07 guidance that recommends 75 percent of the total miscellaneous latent debris transporting to the ECCS sump pool be allotted to sump strainer blockage.

RAI-9:

> Please provide the technical basis for the latent fiber and particulate total mass calculation. Include a description of surface types sampled, the number of samples per surface type, the accuracy of the mass measurement, the method of computing the densities for specific areas, and the extrapolation to the scale of containment.

FINAL NRC STAFF REVIEW:

The final NRC staff review is based on the licensee's July 2, 2012, RAI responses.

Summary of RAI-9:

RAI-9 requested that the licensee provide details regarding the methods used to estimate latent debris amounts within the containments. The RAI requested information regarding the sampling and calculational methodology used for the latent debris calculation. The intent of the RAI was to ensure that the bases for the licensee's assumptions regarding the amount of latent debris are valid.

RAI-9 Licensee Response Summary:

The licensee responded that guidance from NEI 02-01 and NEI 04-07 (including the staff SE) was used to estimate the amount of latent debris within the McGuire containments. McGuire 1 latent debris calculations were used to estimate the amounts for both units since the containments are similar and McGuire 2 was judged to be cleaner by inspection. The licensee categorized surface types within containment and sampled representative areas from each category within four areas of containment. The mass of debris collected was determined by weighing using a scale with a tolerance of 0.04 grams. The licensee statistically evaluated the weights of debris collected in each surface category and extrapolated the results in order to estimate the total latent debris source term in containment. The licensee used a 95 percent confidence interval to develop an estimate of 140 lbm of latent debris per containment. The licensee stated that using a 95 percent confidence value instead of an arithmetic mean adds conservatism to the latent debris value. The licensee adopted the staff baseline guidance amount of latent debris (200 lbm) as its licensing basis source term. The licensee assumed that 15 percent of the latent debris is fibrous.

RAI-9 Acceptability of Response and Basis:

Based on the use of approved guidance and acceptably accurate methodology to determine the amount of latent debris in containment, the NRC staff finds the response to RAI-9 acceptable. Additionally, the staff notes that the licensee added conservatism to the design basis latent debris source term assumption by using a 95 percent confidence value instead of the arithmetic mean, and using the NRC staff guidance value of 200 lbm even though the calculated value was significantly lower. The licensee's methodology is acceptable and provides a margin between the actual latent debris amount and that used in the head loss evaluation.

FINAL NRC STAFF CONCLUSION:

For this review area, the licensee has provided information such that there is reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. The licensee had previously addressed all issues, with the exception of those in RAI-9, within the latent debris area adequately. Since the issues have been adequately addressed by the RAI response, the NRC staff considers the latent debris area to be adequately evaluated by the licensee. Therefore, 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.

INITIAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through April 30, 2008.

The licensee provided the information requested in the content guide. However, there was a problem with the transport results presented by the licensee because they were associated with the old 17D ZOI for fiberglass, which was used for the original nonchemical array testing that the licensee is no longer planning to credit. By letter dated April 30, 2008, the licensee updated the transport results to account for the new 7D ZOI for fiberglass that is being used for the chemical head loss testing that will actually be relied upon to qualify the replacement strainer.

The licensee stated that the methodology used in the debris transport analysis is based on the NEI 04-07 guidance and refinements and the NRC staff SE, including Appendices III, IV, and VI. Logic trees were used to quantify the analysis. Computational fluid dynamics (CFD) was used to calculate containment pool flows during recirculation, and a 4-category debris size distribution for fiberglass was stated to have been used to provide a more refined size distribution to complement the CFD analysis. The licensee assumed that the recirculation transport fractions calculated for Loop B of the RCS can be applied for all breaks because Loop B is closest to the ECCS strainer.

The licensee has not credited the retention of debris in upper containment. The licensee, although discussing Stokes' Law for the settling of fine debris, ultimately has not taken credit the settling of fines. The licensee has not taken credit for holdup of debris in inactive containment pool volumes.

The licensee did not describe any debris interceptors, but stated that debris would have to pass through either crane wall penetrations (varying in size with a diameter of up to 12 inches) or through an enclosure surrounding the portion of the strainer inside the crane wall.

The licensee assumed 10-percent erosion of the fiberglass debris settled in the containment pool but provided no justification for this assumption, such as testing.

CFD was used to calculate containment pool flows during recirculation, and a 4-category debris size distribution for fiberglass was stated to have been used to provide a more refined size distribution to complement the CFD analysis. The licensee assumed that the recirculation transport fractions calculated for Loop B can be applied for all breaks because Loop B is closest to the ECCS strainer. Based upon the information provided, this statement appears reasonable provided that there is confidence that breaks outside the crane wall in the vicinity of the strainer are not more limiting.

RAI-11:

> Please provide the technical basis for the assumption of 10-percent erosion of fibrous debris in the containment pool. If testing was performed to support this assumption, please demonstrate the similarity of the flow conditions, chemical conditions, and fiberglass material present in the test versus the conditions expected in the McGuire containment pool.

FINAL NRC STAFF REVIEW:

The NRC final staff review is based on the licensee's July 2, 2012, RAI responses.

Summary of RAI-11:

RAI-11 requested that the licensee provide the technical basis for the assumption of 10-percent erosion of fibrous debris in the containment pool.

RAI-11 Licensee Response Summary:

The licensee provided a description of a test program designed to evaluate the amount of erosion that could occur to fibrous debris over the strainer mission time. The licensee discussed a vendor test program that was designed to estimate the erosion of fibrous debris. The erosion test found that between 3 and 7 percent of the small and large pieces eroded on average over a 30-day period. The flow rate during the testing was maintained so that the velocity across the fiber samples was equal to the velocity at which the fiber would begin to move if it were within a freely flowing stream. The test also found that the erosion tended to be greatest in the early part of the test and subsequently subsided. The response noted that the test program was reviewed by the NRC and found to provide acceptable justification that the erosion of fibrous debris in the containment pool would be conservatively bounded by the use of the 10-percent assumption.

RAI-11 Acceptability of Response and Basis:

The NRC staff considers the response to RAI-11 to be acceptable because the test program referenced by the licensee was reviewed by the NRC staff and found to be acceptable as a basis for assigning an erosion value to Nukon (and similar) insulation ("Proprietary Erosion Testing of Submerged Nukon Low-Density Fiberglass Insulation in Support of Generic Safety Issue 191 Strainer Performance Analyses," dated June 10, 2010, ADAMS Accession No. ML101540221).

FINAL NRC STAFF CONCLUSION:

The NRC staff had previously determined that the licensee had used approved methodologies for conducting its transport analysis. The only outstanding issue associated with the transport analysis was the assumption of 10-percent erosion of fibrous debris in the sump pool. Since the licensee provided an acceptable justification for the 10-percent erosion assumption for damaged fiberglass in the sump pool, the staff concludes that the transport analysis for McGuire is acceptable. Therefore, the NRC staff considers this item 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.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through April 30, 2008.

The licensee's approach to reducing strainer head loss was to install an array of Enercon top hat strainer modules in place of the original sump strainer. Scaled testing of the strainer modules was conducted both at Alion and at Wyle Laboratories. The Alion testing utilized a 3x2 array and did not include chemical effects, but concentrated on fibrous and particulate debris predicted to reach the strainer following a postulated LOCA. The Wyle testing termed, IPT, was designed to measure the effects of chemicals on head loss. The McGuire strainer area is moderate in comparison to other PWRs at about 1700 square feet. All evaluated breaks initially generated substantial amounts of fibrous debris including significant amounts of fine fibrous debris. However, later debris generation calculations resulted in reductions in the amounts of debris including zero fine fibrous debris. This was not adequately justified by the licensee. The licensee assumed that there would be 200 pounds of latent material within containment of which 30 pounds would be fine fibers. The licensee assumes 374 square feet of labels, tape, and other miscellaneous debris. The Enercon strainer design incorporates internal debris bypass eliminator mesh to reduce strainer bypass. The top hat design has resulted in a somewhat nonuniform debris bed formation during testing.

The NRC staff has witnessed several tests at the Alion laboratory, and also witnessed part of the IPT at Wyle laboratory. Based on these tests, the NRC staff had several concerns with the test methods used to determine the head loss of the McGuire strainer array.

The McGuire evaluation of head loss across the strainer combined an evaluation of clean strainer head loss along with the Alion array test and the Wyle IPT. There were no test results provided by the licensee. In addition, it was not described how the results of the array test and IPT were combined to arrive at a final head loss value. The NRC staff had several concerns with the test methods used for the IPT. These concerns were not addressed by the licensee. The staff concerns with the IPT concentrated on the flow pattern in the test tank and the debris generation and introduction techniques. Similar issues have been noted at Alion tests.

Alion claims that Enercon strainers will not form a thin bed. The characteristics of the top hat do promote nonuniform bed formation. However, it has not been demonstrated to the staff that the degree of this nonuniformity will preclude a thin bed formation if the strainer is tested under prototypical conditions. The NRC staff has noted one case where a relatively thin bed did form on a top hat array.

The strainer is submerged by at least 2 inches during a small break LOCA (SBLOCA) at the onset of recirculation. For a large break LOCA (LBLOCA), submergence is 3 inches and increases due to ice melt and additional refueling water storage tank (RWST) inventory. The strainer is fully submerged and is not vented. It was unclear that the vortex testing performed was conservative with respect to the plant conditions.

Limiting clean strainer head loss (calculated) is 5.3 feet for McGuire 1.

Flow through the strainer is predicted to be a maximum of 15,700 gallons per minute resulting in a strainer approach velocity of 0.021 feet per second (ft/sec) (with no sacrificial area subtracted). The maximum predicted approach velocity (at locations close to the pump suction) is 0.052 ft/sec.

For this review area the licensee did not provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically.

RAIs 12-25:

RAI-12:

Please provide the results of the array testing conducted at the Alion Science and Technology Corporation and the Integrated Prototype Test (IPT) testing conducted at Wyle Laboratories. For the IPT testing, in addition to head loss values, please provide the results as a function of time. Provide a thorough description of the methodology used to combine the two test results to determine the final head loss for the strainer debris bed. If a correlation was developed to determine head loss, provide the correlation along with the assumptions and bases used in the development of the correlation.

RAI-13:

The conditions under which vortex testing was conducted for McGuire, and the plant conditions for which the testing was being conducted, are not clear from the available documentation. Based on the information provided to date, the NRC staff has been unable to determine what conditions resulted in vortex formation and whether the modifications made to eliminate vortices were tested under conditions that conservatively represented those expected in the plant post-LOCA. Vortex testing was conducted at 3-inch submergence (as stated in the Duke Energy Carolinas (Duke) response to RAI question 39 in Enclosure 1 to the supplemental response dated February 28, 2008), which is greater than the expected 2-inch minimum submergence for a small break loss-of-coolant accident (SBLOCA) (as stated in Section 3(f)(2) of Enclosure 2 of the supplemental response). Note that Duke further states in its response to RAI question 39 in Enclosure 1 that the minimum submergence for the strainer is expected to be “at least” 2 inches and separately that it is “about” 4 inches (Enclosure 1, pages 35-36). Enclosure 2, Section 3(f)(2), also states that the strainer is submerged by at least 2 inches while Enclosure 2, Section 3(f)(3), states that the grating is submerged by at least 2 inches. Enclosure 2, Section 3(f)(3), also states that the testing was performed with a “few inches” of submergence. This set of disparate strainer submergence values does not provide a coherent description of the test conditions.

Enclosure 2, Section 3(f)(3), states that the testing was conducted at velocities between 0.01 ft/sec and 0.09 ft/sec, while the maximum approach velocity for the strainer is 0.052 ft/sec. The response does not provide a basis for the 0.052 ft/sec, other than the expected maximum approach velocity is greater than nominal by about a factor of 2 (Enclosure 1, pages 35-36), and does not clearly state that testing at or above 0.052 ft/sec did not result in vortices.

Please provide information that describes the conditions expected in the plant and those present during testing, including the following information:

a. Please clarify what the actual minimum submergence for the strainer is expected to be in the plant.

b. If different evaluations for vortexing were conducted for SBLOCAs and large break loss-of-coolant accidents (LBLOCAs), please provide details for each evaluation.

c. Please provide the basis for the maximum approach velocity.

d. Please provide a quantitative value for the approach velocity during which vortices were observed to form when no vortex suppressors were installed.

e. Please provide a quantitative value for the submergence level at which the testing was conducted with no vortex suppressors installed. If the level changed (e.g between SBLOCA and LBLOCA tests), please provide the test conditions for each test.

f. Please provide information for testing that was conducted with the vortex suppression grating in place, including the minimum submergence and maximum approach velocities that were present when vortices did not occur.

g. Provide a quantitative value for the vortex suppressor submergence in the reactor plant. If some suppressors are installed at different elevations than others, provide the submergence level for each location.

RAI-14:

Please provide a response to the question from the revised NRC Content Guide sent by letter dated November 21, 2007, relating to Enclosure 2 of the supplemental response dated February 28, 2008, Section 3(f)(5), regarding the ability of the strainer to accommodate the maximum potential debris volume. This response should apply specifically to the McGuire strainer and not be a general answer (as is found in Enclosure 2, Section 3(f)(5)). The McGuire response to Enclosure 1, RAI question 40, sends the reader to Enclosure 2, Sections 3(f) and 3(o) to find this information. The information is contained in neither location.

RAI-15:

Please provide information that verifies that the debris preparation and introduction methods used during the array test and IPT were prototypical or conservative with respect to the transport evaluation for the plant. In general, protocols for fibrous debris preparation result in debris that is coarser than predicted by the plant-specific transport calculation. In addition, the NRC staff has noted that debris introduction frequently results in agglomeration of debris such that it may not transport to the strainer prototypically or create a prototypical debris bed. Both of these issues can result in non-conservative head loss values during testing.

RAI-16:

Please provide information on the flow fields in the array test. The NRC staff is concerned that non-prototypical debris distribution may have occurred during testing caused by stirring of the tank. The stirring can result in the transport of debris that would otherwise not transport, or result in washing debris from the strainer screen surfaces. Either of these phenomena can result in reduced (non-conservative) head loss values during testing.

RAI-17:

Please provide debris preparation and introduction information similar to that requested in this enclosure, RAI question 15, for the testing that was used to justify that a thin bed would not form on a top hat strainer. Note that for thin bed testing, the NRC staff considers it prototypical or conservative for fine fiber to arrive at the strainer prior to less transportable debris. Overly coarse debris preparation or non-prototypical introduction to the flume may non-conservatively affect the potential for thin bed formation.

RAI-18:

Please provide the criteria used to judge that differential pressure-induced effects (e.g., boreholes) did not occur during testing.

RAI-19:

Please provide the scaling parameters used for calculation of debris quantities and strainer approach velocities used during testing. State whether the scaling accounted for strainer areas blocked by miscellaneous debris such as labels and tape.

RAI-20:

Please provide information on whether the amount of coatings surrogate was adjusted for the volume difference created by the difference in density between the surrogate material and the potential debris in the plant.

RAI-21:

Please discuss the NRC staff's observation that in the IPT the flow was non-prototypically directed at the top-hat strainer in a direction parallel to the strainer long axis. Please address whether this non-prototypical flow direction could result in a non-prototypical formation of debris on the top hat strainer.

RAI-22:

Please provide the clean strainer head loss for McGuire Unit 2 (only the clean strainer head loss for McGuire Unit 1 was provided).

RAI-23:

The supplemental response stated that the total head loss across the McGuire Emergency Core Cooling System Sump strainer (clean strainer head loss plus debris bed head loss) was conservatively predicted to be 9.8 ft at switchover to sump recirculation. No explanation was provided as to how this value was derived. It appears that the licensee is taking credit for time-dependency in head loss, since the 30-day value is 15.7 ft. Please provide the time-dependent results and calculation methodology for determining net positive suction head margin throughout the 30-day mission time.

RAI-24:

Please provide the types and amounts of debris added to each test (Array and IPT). Include information on introduction sequence. Please provide relevant test parameters such as temperature, debris introduction times, and flow rate for the Array and IPT tests.

RAI-25:

Please provide information on the amounts of debris that settled during testing for each test (IPT, Array, and Thin Bed). Note that Enclosure 1, response to RAI question 37, states that near-field settling was not credited during testing. However, the NRC staff observed significant settling during the IPT. Please provide a quantitative evaluation of how this settling affected head losses for each test. Please state whether this settling is prototypical of plant conditions and provide a basis for the conclusion.

FINAL NRC STAFF REVIEW:

The NRC final staff review is based on the licensee's July 2, 2012, RAI responses.

Summary of RAI-12:

RAI-12 requested that the licensee provide the results of two different test programs that were combined to develop an estimated strainer head loss that included both nonchemical and chemical debris. The RAI also requested that the methodology used to combine the test results be provided.

RAI-12 Licensee Response Summary:

The licensee stated that the RAI as posed by the staff is no longer applicable because McGuire performed additional testing, which superseded the previous tests. The new test program was implemented so that the issues identified in RAI-12 were addressed by using test methods accepted by the staff. The head loss results were not attained by combining two test results, but from a single test that included both nonchemical and chemical debris. The licensee provided the results of the strainer head loss test as a function of strainer mission time. The head loss evaluation assumes that chemicals do not precipitate until the pool temperature decreases below 156 degree Fahrenheit (F). The evaluation also corrects the head loss results to account for varying sump fluid temperatures.

RAI-12 Acceptability of Response and Basis:

The NRC staff reviewed the licensee's test methods by traveling to the test site and conducting several follow up phone calls and meetings with the licensee. Through these interactions and based on information submitted by the licensee, the NRC staff determined that the final test results were acceptable because the tests of record were performed in accordance with staff guidance for strainer head loss testing. Both the temperature dependent precipitation assumption and the temperature correction for fluid temperature are methods that have been approved by the staff. Therefore, the response to RAI-12 is acceptable.

Summary of RAI-13:

RAI-13 requested that the licensee provide additional information and justification for conditions under which vortex testing of the strainer was conducted. Important variables during the test are approach velocity and strainer submergence level, so these were the areas concentrated on by the RAI. The intent of the RAI is to ensure that the testing was conducted under the most limiting conditions that could realistically occur at McGuire.

RAI-13 Licensee Response Summary:

The licensee provided information regarding the test methodology, the approach velocities used during testing, the strainer submergence, and the bases for these values. The licensee provided information that shows that both the approach velocity and the submergence used during vortex testing was significantly conservative with respect to expected post-LOCA conditions. Additionally, since the testing was completed, McGuire has reduced the maximum flow rate through the strainer by 25 percent. This decreases velocity and increases the margin to vortexing.

RAI-13 Acceptability of Response and Basis:

The NRC staff concluded that the licensee showed that the test conditions were conservative when compared to the design basis plant conditions. Testing showed that vortex formation would not occur under conditions conservative with respect to the plant. Therefore, the response to RAI-13 is acceptable.

Summary of RAI-14:

RAI-14 requested that the licensee provide information that shows that the strainer array installed at McGuire can accommodate the maximum potential debris volume that may transport to the strainer. The RAI is intended to insure that the strainer array will not be completely engulfed with debris or that testing adequately modeled such a condition.

RAI-14 Licensee Response Summary:

The licensee stated that significant amounts of fibrous debris have been removed from the McGuire containment and stated that the bounding amount of fiber that could transport to the strainer is about 73 ft^3 (reduced to approximately 69 ft^3 after implementation of water management, which has now been completed). McGuire also provided the design basis volumes of other materials, which could become damaged and transport to the strainer. The total volume of debris predicted to reach the strainer is about 92 ft^3 and the interstitial volume of the strainer was reported as about 346 ft^3 for the limiting (smaller) strainer (McGuire 1). The licensee noted that the debris will collect nonuniformly on the strainer and is not of sufficient volume to fill the strainer interstitial volume. Therefore, the licensee concluded that the analyzed flow velocities remain bounding.

RAI-14 Acceptability of Response and Basis:

The NRC staff concluded that the response to RAI-14 is acceptable because the limiting amount of debris that could reach the strainer is significantly less than the interstitial volume of the strainer. The NRC staff also noted that the density (as-manufactured) used to determine the fibrous debris volume is likely significantly lower than the density of the fiber once it collects on the strainer so the volume assumed in the evaluation is conservative. Therefore, the strainer will not become engulfed with debris and the testing performed to evaluate the strainer is valid.

Summary of RAI-15:

RAI-15 requested that the licensee verify that the debris preparation and introduction methods used during head loss testing were prototypical or conservative with respect to the expected plant condition following a LOCA. The RAI concerns the fact that some strainer tests were conducted with fiber not prepared as finely as the plant evaluation predicts. This could cause nonconservative head loss results.

RAI-15 Licensee Response Summary:

The licensee stated that the concerns regarding debris preparation and introduction were based on early testing and that these concerns required additional testing to be completed. The RAI response stated that debris preparation and introduction methods for newer testing were based on staff guidance on head loss testing and also on discussions with the staff. For the more recent testing, the debris was well diluted and inspected to ensure that it met the desired size distribution. The licensee stated that shakedown tests were conducted to ensure that agglomeration would not occur and that the majority of the fiber would transport to the strainer. The licensee also stated that the staff observed video and photographs of the debris preparation and introduction during testing.

RAI-15 Acceptability of Response and Basis:

Based on the licensee description of the debris preparation, inspection, and introduction methodology and NRC interactions with the licensee during testing, the NRC staff was able to conclude that the McGuire testing was conducted using methods accepted by the NRC staff. Therefore, the response to RAI-15 is acceptable.

Summary of RAI-16:

RAI-16 requested that the licensee provide information regarding the flow fields present during the array testing because there was concern that nonprototypical and potentially nonconservative debris distribution over the strainer may have occurred during the testing due to stirring in the tank.

RAI-16 Licensee Response Summary:

The licensee stated that the staff NRC observation of potentially nonprototypical debris distribution over the strainer surface would be resolved by performing additional testing. The licensee stated that the new test facility was designed to prevent nonprototypical debris bed formation by installing a baffle between the agitators and strainer array. This allowed the debris to be maintained in suspension and transport to the strainers without adversely affecting the deposition of debris on the strainer array.

RAI-16 Acceptability of Response and Basis:

The licensee test facility was discussed with the staff and observed via photographs and video. Based on the NRC staff observations and the fact that the agitators were placed so that they could not affect the morphology of the debris bed, the response to RAI-16 is acceptable.

Summary of RAI-17:

RAI-17 requested that the licensee provide information that verified that the debris preparation and introduction practices used during thin bed testing were prototypical with respect to the sites debris generation and transport evaluation, and that the debris addition order was in accordance with staff accepted guidance. The RAI is intended to ensure that the debris met accepted criteria for fine sizing and that the fine debris was added first since it is the most likely to transport.

RAI-17 Licensee Response Summary:

The licensee stated that additional testing was performed after the staff developed the RAI. Some of the newer tests were specifically designed to determine whether the McGuire strainers were susceptible to high head losses from a thin, relatively low porosity debris bed. The testing included both testing that added all particulate first followed by incremental batches of fiber and testing that added small batches of particulate and fibrous debris simultaneously. The licensee noted that the thin bed test protocol, or particulate debris followed by incremental fiber additions resulted in higher head losses. However, the thin bed testing did not ultimately result in the highest head losses for the McGuire strainer. The debris preparation was noted as being described in RAI-15. Debris introduction was noted as being described in RAI-16.

RAI-17 Acceptability of Response and Basis:

The NRC staff had several telephone calls with the licensee (after the RAI had been sent to the plant) during their test program to discuss the methodology and results. The licensee also provided video and photographic depictions of the testing to the NRC staff. The two thin bed test methods described in the response to RAI-17 are both NRC staff accepted thin bed methodologies. One method adds all particulate prior to adding any fibrous debris and the other method adds proportional amounts of particulate and fiber in small increments. The fact that the licensee used both methodologies and chose the limiting method ensures conservatism in the strainer head loss evaluation. Based on the use of NRC staff approved methodologies, the response to RAI-17 is acceptable.

Summary of RAI-18:

RAI-18 requested that the licensee explain how it was determined that pressure induced effects did not occur during testing. This RAI is intended to ensure that any viscosity based temperature scaling performed is conservative.

RAI-18 Licensee Response Summary:

The licensee stated that all tests included flow sweeps, as recommended by staff guidance, to ensure that temperature scaling of the head loss tests was conducted correctly and that pressure driven debris bed breakdown did not limit the head loss. The results of the flow sweeps were used to scale the head loss test results to various temperatures predicted to occur at different times after a postulated LOCA. The temperature scaling was discussed further in the response to RAI-12.

RAI-18 Acceptability of Response and Basis:

The NRC staff guidance states that flow sweeps should be conducted to determine whether head loss across the debris bed responds relatively linearly to flow changes before scaling the test results for temperature driven viscosity changes. Instead of applying a direct viscosity correction, the licensee based the scaling on the results of the flow sweeps for the tests of record. This methodology is acceptable to the NRC staff since it applies less credit than a straight viscosity correction and, is therefore, more conservative. Therefore, the response to RAI-18 is acceptable.

Summary of RAI-19:

RAI-19 requested that the licensee provide the scaling parameters used to calculate the amount of debris added to the strainer head loss tests and the flow velocities used during testing. The purpose of this RAI is to ensure that the important test parameters were scaled properly with respect to the plant.

RAI-19 Licensee Response Summary:

The licensee stated that the scaling was based on the ratio of the smaller of the two units' surface areas (Unit 1) minus an area penalty for tags and labels that could block some of the strainer surface to the area of the test strainer. This scaling ratio was used for both the debris and velocity scaling for the test. The licensee also stated that the velocity scaling was based in ECCS water management flows.

RAI-19 Acceptability of Response and Basis:

The scaling was performed in accordance with accepted staff guidance. The use of ECCs water management flows is acceptable because the NRC staff has approved an LAR for McGuire to run only a single train of containment spray instead of the original design, which started two trains of spray. Therefore the response to RAI-19 is acceptable.

Summary of RAI-20:

RAI-20 requested that the licensee provide information on whether the amount of coating surrogate added to head loss testing was adjusted for volume differences created by differences in density between the coating material and the surrogate used in testing.

RAI-20 Licensee Response Summary:

The licensee stated that the amount of coating surrogate added to the test was scaled appropriately as discussed in the responses to RAIs 19 and 24. The licensee stated that the test program accounted for density differences between the coating material and the surrogates used in the testing.

RAI-20 Acceptability of Response and Basis:

The amount of coating surrogate debris was adjusted to account for the difference in density between the surrogate and the coating that it represented in the testing. Therefore the response to RAI-20 is acceptable.

Summary of RAI-21:

RAI-21 requested that the licensee provide additional information regarding the flow patterns that occurred during the early testing that may have resulted in a nonconservative debris bed distribution on the strainer.

RAI-21 Licensee Response Summary:

The licensee stated that the results of the earlier testing (IPT) were not used for the strainer design basis head loss. Later testing was conducted per staff guidance with the debris preparation and introduction described in RAIs 15 and 16 of this submittal.

RAI-21 Acceptability of Response and Basis:

The debris introduction and preparation for more recent testing has been accepted in RAIs 15 and 16. The results of the test in question were not used for the strainer design basis. The response to RAI-21 is acceptable based on the acceptable methodologies used for the most recent testing, which provides the design basis head loss for the McGuire strainer.

Summary of RAI-22:

RAI-22 requested that the licensee provide the clean strainer head loss value for the McGuire 2 strainer because it had not previously been provided.

RAI-22 Licensee Response Summary:

The licensee provided both the Unit 1 and Unit 2 clean strainer head loss values. The Unit 1 value is slightly smaller than the Unit 2 value (3.55 ft vs. 3.69 ft). The clean strainer head loss values were reduced from previously submitted values because of the flow reductions realized through water management.

RAI-22 Acceptability of Response and Basis:

The NRC staff finds that it is acceptable to base the clean strainer head loss values on water management flow rates since these are the design basis flow rates for the strainer. Because the licensee provided the requested information, the response to RAI-22 is acceptable.

Summary of RAI-23:

RAI-23 requested that the licensee provide the time dependent test results and methodology for determining the NPSH margin throughout the strainer mission time. This RAI concentrated on the issues arising from combing test results to derive this information.

RAI-23 Licensee Response Summary:

The licensee stated that the original test program was abandoned and a new test program undertaken to determine the strainer head losses to be applied to the NPSH calculations. The licensee referenced the response to RAI-12, which calculated the temperature (and time) dependent head losses based on the head loss under the NPSH section of the RAI responses. The RAI response also provides a table of the mission time, strainer head loss, and margins to NPSH required and strainer structural limits as a function of temperature. The values in this table were calculated using limiting conditions.

RAI-23 Acceptability of Response and Basis:

Based on the updated testing and evaluation conducted by the licensee, which was conducted using staff accepted guidance as discussed in several RAIs in this section, the response to RAI-23 is acceptable. The NRC staff especially considered the response to RAI-12, which provided the methodology used to extrapolate the test results to alternate temperature conditions. As concluded in RAI-12, the methodology used was acceptable. Therefore, the time/temperature dependent inputs from the head loss test evaluation to the NPSH evaluation are acceptable.

Summary of RAI-24:

RAI-24 requested that the licensee provide the amounts of debris added, flow rates, and temperatures for the early strainer head loss tests. This RAI is intended to gain information to understand how the tests were conducted to ensure that they were performed in a realistic or conservative manner and to determine whether the licensee's methodology of combining test results was justified.

RAI-24 Licensee Response Summary:

The licensee stated that the early tests were discussed with the NRC during public meetings in Washington, D.C. and that it was decided that additional testing and analysis would be required to adequately evaluate the strainer performance. The licensee provided the debris amounts, debris introduction procedures, the temperatures, and the flow rate used in the more recent testing that was conducted using staff approved guidance. The RAI response noted that the scaling for testing was discussed in the response to RAI-19.

RAI 24 Acceptability of Response and Basis:

Because the licensee conducted updated testing that was performed using staff approved guidance, the issue identified by the RAI was resolved by the new testing. As discussed in other RAI responses in this section the latest testing was performed in accordance with NRC-approved guidance. The NRC staff's concern with the earlier testing is no longer an issue. Therefore the response to RAI-24 is satisfactory.

Summary of RAI-25:

RAI 25 requested that the licensee provide estimates of the amounts of debris that settled during early head loss testing. This RAI is intended to ensure that excessive settling of debris did not occur during testing resulting in nonconservative head loss results and was based on NRC staff observations of early McGuire strainer testing.

RAI-25 Licensee Response Summary:

The licensee stated that near field settling was not credited in the evaluation of the McGuire sump strainers. The licensee noted that updated testing was completed and that RAI-15 discussed the methods used to ensure that the majority of debris transported to the test strainer. Also, the licensee stated that the response to RAI-16 provided details on the tank design, which contributed to ensuring transport of debris to the strainer.

RAI-25 Acceptability of Response and Basis:

Based on the updated testing conducted by the licensee and the responses to RAIs 15 and 16, the staff concluded that excessive settling of debris did not occur during the testing of McGuire's strainer. Therefore, the response to RAI-25 is acceptable.

NRC STAFF CONCLUSION:

The NRC staff had previously determined that the licensee had used approved methodology for conducting its strainer head loss and vortexing evaluation in all areas except those addressed by RAIs 12-25. It should be noted that the issues described in the RAIs are significant and these issues led the licensee to abandon their early test program, make significant modifications to improve the performance of the ECCS system, and develop a test program to evaluate the upgraded plant conditions. Because the licensee reperformed its head loss testing and evaluations using procedures acceptable to the NRC staff, the NRC staff finds that the testing and evaluation are acceptable and result in a design basis head loss that will reasonably bound any potential head loss that may occur across the strainer following a LOCA. Therefore, the NRC staff concludes that the head loss and vortexing evaluation for McGuire is acceptable. The NRC staff considers this item 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.

FINAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through April 30, 2008.

The licensee provided the content guide specified information but with a minimum of explanatory or supporting detail. The RHR and CS pump flows at available NPSH and at required NPSH were provided as representative pump flow rates along with a maximum analyzed recirculation (sump) flow rate of 16,000 gallons per minute (from both the RHR and CS pumps in hot leg injection). The licensee's February 28, 2008, supplemental response, Table 3G1-1, shows pump flows at available NPSH less than flow at required NPSH, and the licensee's supplemental response dated April 30, 2008, Tables 12-3/4/5 show the total sump flow. Individual pump flow rates at this maximum calculated sump flow rate were not provided, but the UFSAR assumption of the RHR pumps operating at runout apparently is being changed so that NPSH required is for some lesser calculated maximum flow rate. The pump curve figures in the McGuire UFSAR suggest the flow rates shown in the supplemental response are reasonable and conservative. The supplemental response indicated that the limiting NPSH available would occur early in the accident due to the water vapor pressure drop throughout the accident more than compensating for the strainer debris loading head loss. Pool temperature at the beginning of ECCS sump pool recirculation was identified as being 190 degree F and that was used in determining minimum NPSH available and NPSH margin. The February 28, 2008, supplemental response describes the minimum containment water level as being 36 inches above the containment/sump floor, which is 2 inches above a vortex suppressor installed above the strainer and 4 inches above the top of the highest point of perforated plate strainer surface. This level is calculated using the assumption of a SBLOCA where CS is not actuated and there is no contribution from melting of the ice.

The licensee describes the assumptions used for determining the pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level as follows:

- Accident containment overpressure is not credited for NPSH available.

- Containment ECCS sump pool temperature is 190 degree F. (Higher pool temperature results in lower NPSH margin as vapor pressure contribution dominates. Decreasing temperatures result in increasing strainer head loss as the pool cools to 90 degree F. The UFSAR discussion of containment response shows a maximum sump water temperature of 173 degree F, so the 190 degree F value is conservative relative to NPSH margin determination.) Available NPSH determination assumes a pool water level of 725 foot elevation, or the Containment/sump floor. Calculated actual minimum water level is stated as being 36 inches above this level.

- RHR/CS pump required NPSH is taken from the pump curves at a flow rate above that achievable based on downstream flow path (system) resistance.

- All RHR/CS pumps have similar hydraulic capabilities.

- Overall system configurations/flow resistance and thus flow rates are similar, with the exception of the 2B CS Heat Exchanger, which has spray flow on the shell side and thus a somewhat lower system resistance. Suction piping from the ECCS sump have similar configurations and flow resistances.

- Minimum pool water level determination assumes a small break of indeterminate size which fills up the incore instrumentation room (located below the reactor vessel), but has insufficient energy to cause the CS to actuate, the ice condenser doors to open, or result in accumulator injection. For larger break sizes these additional water sources would result in a higher pool level. For the minimum pool water level determination, no ice melting contributes to the pool inventory. Pool water inventory contributions include the technical specification minimum inventory from the RWST down to the RWST low-low level setpoint, which is conservatively error-adjusted upward to minimize the usable RWST volume. The following ECCS sump inventory penalties (lost water sources) are applied in the small break minimum pool level analysis:

    - RCS shrinkage
    - Incore instrumentation room diversion
    - Volume Control Tank diversion
    - Pressurizer Relief Tank diversion
    - Lower containment ventilation system condensation diversion (loss of lower containment condensate through drain pans and drain lines)

For larger break sizes the upper containment holdup volumes that come into play and are accounted for include refueling canal, refueling deck (3-inch curb), CS piping volume, airborne droplets, and water draining down vertical surfaces.

The licensee's supplemental response indicated that the required NPSH values were taken from the pump head curves and that flow rates greater than the hydraulic model calculated values were used. The supplemental information did not identify if the 3-percent head drop criterion was applied in the development of these curves, but it would be reasonable to assume this common industry practice applied.

The supplemental response indicated that for the ECCS/CS piping systems, hydraulic models were generated using standard methodologies, which apply appropriate resistance coefficients and friction factors. No specific methodology or source reference was provided, which is similar detail to the McGuire original UFSAR discussion on this topic.

The supplemental response provided the limiting NPSH margin for CS as being 1 foot of water and the margin for RHR as being 4.6 feet. These limiting margins were stated as occurring at or very near the start of sump recirculation flow when strainer debris loaded head loss is predicted to be 9.8 feet of water and pool temperature is assumed to be 190 degree F. The supplemental response states that strainer differential pressure losses are time dependent and (are more than) offset by vapor pressure reduction and sump pool level increase during the accident period.

The NPSH available calculation assumes a containment pool water level of the containment/sump floor elevation while the minimum calculated pool water level when starting recirculation flow from the sump is 36 inches above that.

FINAL NRC STAFF CONCLUSION:

For this review area, the licensee has provided information such that the reviewer has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. The NRC staff has determined that the licensee had used approved methodology for conducting its NPSH evaluation in all areas except as it was affected by the strainer head loss evaluation. Because the licensee reperformed its head loss testing and evaluations using procedures acceptable to the NRC staff, the NRC staff finds that its use as an input to the NPSH calculations result in conservative NPSH and strainer structural margins. Therefore, the NRC staff concludes that the NPSH evaluation for McGuire is acceptable. The NRC staff considers this item 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.

INITIAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through April 30, 2008.

The break ZOI used for calculating the amount of qualified epoxy coating debris was 5D, which is acceptable by WCAP-16568-P-A. All qualified and unqualified coatings in the ZOI fail as fine particulate and all debris generated by unqualified coatings in containment fail as fine particulate to maximize transport, which is acceptable by the NRC SE to NEI 04-07. Debris transport assumed that 100 percent of the coating debris particulate would transport to the sump and was used in head loss testing, which is acceptable by the NRC SE to NEI 04-07.

The surrogate material used for testing is acceptable to the NRC staff since the particle size and density are similar to the coating particles.

The licensee's coating assessment program is acceptable to the NRC staff since the licensee's assessment is conducted during each refueling outage, is conducted by qualified personnel, and, if degraded coatings are identified, these areas are documented and additional tests and remediation may be performed.

The unqualified epoxy coating debris quantities and transport metrics were refined using the Electric Power Research Institute (EPRI) analysis of original equipment manufacturer (OEM) coatings. It was assumed that the unqualified coatings at McGuire were similar to those used in the EPRI analysis. The staff questioned whether the unqualified epoxy coatings at McGuire are similar to those used in the EPRI analysis. The staff also requested a clarification of the actual amount of calculated epoxy coatings debris used in the analysis.

RAI-26:

> Please provide verification that the unqualified epoxy coatings at McGuire are similar to the coatings used in the Electric Power Research Institute's analysis of

original equipment manufacturer coatings. Also, are plant records maintained for the unqualified coatings in order to track quantities and composition?

RAI-27:

Please clarify the discrepancy in quantitative values for unqualified epoxy coatings debris in Enclosure 2 to the supplemental response dated February 28, 2008, response to Section 3(e)(6), Tables 3E6-1 and 3H6-2.

RAI-26 Licensee Response Summary:

The licensee responded that, "it was assumed that the unqualified epoxy coatings inside the containments at McGuire were similar to the epoxy coatings used in the EPRI testing. The coatings sampled [by EPRI] included OEM and non-OEM applied epoxies in a wide age range, which are representative of the type existing in the McGuire containments. The majority of unqualified epoxy coatings inside the McGuire containments are vendor-applied to OEM components and equipment, applied via a controlled method as described in the EPRI report. The epoxy-coated test coupons described by the EPRI test report and analysis are therefore appropriately representative of unqualified coatings in the McGuire containments."

The licensee also stated that, "plant records are maintained for all unqualified coating in containment in a calculation file."

RAI-26 Acceptability of Response and Basis:

From EPRI report 1011753, only 50 percent of epoxy OEM coatings fail as fine particulate. From the NRC review guidance, the reduction/refinement can only take place if the epoxy OEM coatings at McGuire are consistent with the epoxy OEM coatings in the EPRI report.

The NRC staff asked RAI-26 on this issue and has reviewed the information provided in response to RAI-26. The licensee's response is satisfactory because the licensee stated, "[t]he coatings sampled [by EPRI] included OEM and non-OEM applied epoxies in a wide age range, which are representative of the type existing in the McGuire containments." Also the licensee stated that, "[t]he majority of unqualified epoxy coatings inside the McGuire containments are vendor-applied to OEM components and equipment, applied via a controlled method as described in the EPRI report." And that, "[t]he epoxy-coated test coupons described by the EPRI test report and analysis are therefore appropriately representative of unqualified coatings in the McGuire containments." These statements demonstrate that a comparison was done by McGuire, and they verified that their unqualified epoxy coatings were representative. The 50-percent failure rate provides some margin because, in general, the epoxy coatings tested performed much better than 50-percent failure. Therefore, the refinement of the unqualified coatings is acceptable.

The NRC staff reviewed the second part to the RAI and found it to be acceptable since the licensee is tracking the unqualified coatings in containment and they are maintained.

RAI-27 Licensee Response Summary:

The licensee has clarified the difference between the tables. Table 3E6-1 represents the initial unqualified epoxy coatings quantity predicted to transport to the ECCS sump pool after a LBLOCA event with no refinements. Table 3H6-2 represents the refined unqualified epoxy coatings quantity predicted to transport to the ECCS sump pool after a LBLOCA.

RAI-27 Acceptability of Response and Basis:

The NRC staff has reviewed the response to RAI-27 and has found that the information provided sufficient clarification.

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 coatings evaluation for McGuire 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.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through April 30, 2008.

The licensee provided a high level description of the programmatic controls that will ensure that potential sources of debris introduced into containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. The licensee referenced in its response the actions taken to address Bulletin 03-01. It is not clear to the NRC staff if the containment cleaning practices mentioned in the response are controlled administratively or if these are permanent activities at McGuire.

The licensee's August 7, 2003 (ADAMS Accession No. ML032260651), response to Bulletin 03-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors," described planned actions regarding containment cleanliness. These actions have been implemented and provide for containment cleaning and visual inspections.

Containment cleaning is conducted prior to entering Mode 4.

Extensive containment cleaning is conducted using water spray. In general, washdowns are limited to the space in lower containment that would be submerged under LBLOCA conditions. Accessible floor and wall surfaces and mechanical equipment are washed down. Localized washdowns are performed as directed by radiation protection personnel. Visual inspections are performed on remaining areas of containment. Debris that is identified is cleaned or removed, as necessary.

As part of the housekeeping/material condition programmatic controls, containment cleanliness at McGuire is verified prior to entry into Mode 4 by a procedurally controlled inspection. This cleanliness inspection ensures that the ECCS sump area is free of debris. Containment foreign material exclusion (FME) controls and inspection activities are implemented during Modes 1 through 4. McGuire FME control practices and inspection activities assuring containment cleanliness during Modes 1 through 4 are described as follows:

- Containment entries during normal power operations are controlled by an administrative procedure. Increased material accountability control at McGuire is achieved by requiring material accountability logs be kept for items carried into and out of containment during normal power operations (Modes 1 through 4).

- The licensee's modification process currently includes an administrative procedure that directs the design and implementation of engineering changes in the plant. This procedure directs that engineering changes be evaluated for system interactions. As part of this evaluation, there is direction to include consideration of any potential adverse effect with regard to debris sources and/or debris transport paths associated with the containment sump.

The licensee has established controls for procurement, application, and maintenance of the licensee's applied, Service Level 1 protective coatings used inside containment. The licensee also stated that extensive containment cleaning is performed during each refueling outage using water spray, vacuuming and hand wiping. Localized washdowns are performed as needed and visual inspections are performed on the remaining areas of containment. Foreign material is removed as necessary.

The plant labeling process has been enhanced to require that any additional labels or signs placed inside containment be evaluated to ensure that the design basis for transportable debris is not invalidated.

McGuire Technical Specification (TS) Surveillance Requirement (SR) 3.5.2.8 requires that the ECCS sump be visually inspected to verify there are no restrictions as a result of debris and no evidence of structural distress or abnormal corrosion present prior to declaring the ECCS sump operable. A visual inspection of containment is performed to ensure no loose material is present, which could be transported to the containment sump and cause restriction of the ECCS pump suction during accident conditions prior to the transition from Mode 5 to Mode 4 operations. When these inspections are performed, major outage work is complete, and any remaining loose material in containment must be logged and tracked in accordance with station procedures for control and accountability. If any debris, damage, or deficiency were to be discovered during the inspection, station processes require entry into the corrective action program, with the requisite investigation and implementation of appropriate corrective action prior to the transition from Mode 5 to Mode 4.

Additionally, McGuire Selected Licensee Commitment 16.6.1 ensures that a visual inspection is performed to identify any loose debris inside containment and ensure it is removed prior to establishing containment

The licensee stated that to ensure compliance with 10 CFR 50.65a(4), risk assessments are performed prior to conducting any maintenance at McGuire. Maintenance includes all activities traditionally associated with identifying and correcting degraded conditions including corrective maintenance, plant engineering changes, and preventive maintenance including surveillance, predictive and preventive activities.

If a structure, system, or component (SSC) is required to be available with a temporary alteration in place, an evaluation of the effects of the alteration must be performed. Only after the evaluation can the SSC be determined to be available with temporary alterations in place. For activities that install other temporary alterations such as scaffold, lead shielding, and supports, programs are in place to evaluate and control the effects of those alterations.

Modification of Existing Insulation:

The licensee stated that Microtherm® insulation installed on the McGuire 1 and 2 reactor vessel heads was removed and replaced with RMI. .

Modification of Other Equipment or Systems:

Electromark® labels have been evaluated as capable of withstanding the limiting break in all areas of containment except inside the crane wall in lower containment, and the miscellaneous latent debris quantification has been adjusted accordingly. Duke's modification process currently includes an administrative procedure that directs the design and implementation of engineering changes in the plant. This procedure directs that engineering changes be evaluated for system interactions. As part of this evaluation, there is direction to include consideration of any potential adverse effect with regard to debris sources and/or debris transport paths associated with the containment sump.

Modification or Improvement of the Coatings Program:

The licensee stated that a primary containment coatings condition assessment is conducted during each refueling outage or any other extended outage. The primary containment coating condition assessment protocol consists of a visual inspection of all readily accessible coated areas by qualified personnel. When degraded coatings are visually identified, the affected areas are documented in accordance with plant procedures. Additional nondestructive and/or destructive examinations are conducted as appropriate to define the extent of the degraded coatings and to enable disposition of the coating deficiency. The guidance contained in EPRI TR-109937, "Plant Support Engineering: Guideline on Nuclear Safety-Related Coatings," Revision 2, dated December 23, 2009, is used including;

1. Performance of additional in situ and/or laboratory testing of degraded coatings,
2. Removal and replacement of degraded coatings,
3. Repairing degraded coatings,
4. Mitigation of accident consequences related to failure of degraded coatings,
5. Leaving coating in place based on evaluation of effects of failure (detachment) of the degraded coating on ECCS system performance, and/or
6. Upgrading of indeterminate coatings.

If, after identification, degraded qualified/acceptable coatings will be left in place during plant operation, the degraded qualified/acceptable coatings are assumed to fail and to be available for transport to the ECCS sump. After each containment coatings condition assessment, the quantity listing of degraded coatings is updated, and the revised quantity of degraded coatings is verified to meet the acceptance limit in the ECCS debris source term analysis.

RAI-28:

> Please identify and describe the main features of any procedures that comprise containment cleanliness practices.

RAI-29:

> Please provide the technical basis for the conclusion that all labels are capable of withstanding post-LOCA conditions in containment except inside the crane wall in lower containment.

FINAL NRC STAFF REVIEW:

The NRC final staff review is based on the licensee's July 2, 2012, RAI responses.

Summary of RAI-28:

RAI-28 requested that the licensee identify and describe its containment cleanliness procedures for McGuire.

RAI-28 Summary of Licensee Response:

The licensee stated that they have instituted programmatic controls to ensure that potential sources of debris that may enter containment will be assessed to determine if they could adversely affect the recirculation functions. The licensee stated that these controls had been identified in their supplemental response dated February 28, 2008, in item 3(i)(1).

The programmatic controls include:

- During each refueling outage, extensive containment cleaning is performed using water spray, vacuuming, and hand wiping. Localized washdowns are performed as needed and visual inspections are performed in the remaining areas of containment. Foreign material is removed as necessary.

- The licensee performs visual inspections of the ECCS strainer to evaluate sump availability, cleanliness, and structural soundness. After the inspection is completed, any remaining loose material in containment is tracked.

- Material accountability controls track items taken into and out of containment in Modes 1 through 4.

- Prior to establishing containment integrity a visual inspection is conducted to identify and remove loose debris inside containment. The inspection is performed after containment entries after containment integrity is established.

Administrative procedures implement the licensee's commitments made in response to Bulletin 03-01 and GL 2004-02 as described in the licensee's response.

RAI-28 Acceptability of Response and Basis:

The licensee has implemented controls intended to maintain containment cleanliness and ensure that foreign materials do not adversely affect the operation of the recirculation functions for ECCS and CS. The controls are those typically used throughout industry and have been generally effective in limiting undesirable materials to an acceptable level. Therefore, the response to RAI-28 is acceptable.

Summary of RAI-29:

RAI-29 requested that the licensee provide the technical basis for the conclusion that all labels within containment except those within the lower crane wall would not fail.

RAI-29 Licensee Response Summary:

The licensee stated that the information requested in RAI-29 was included in the response to RAI-8.

RAI-29 Acceptability of Response and Basis:

The staff accepted the response to RAI-8 and also concluded that it is applicable to RAI-29. Therefore, the licensee's response to RAI-29 is acceptable.

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

12.0 SCREEN MODIFICATION PACKAGE

NRC STAFF REVIEW:

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

The NRC staff review is based on documentation provided by the licensee through April 30, 2008.

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

- The modified ECCS sump strainer assembly design for McGuire removed the original ECCS sump structure and replaces it with strainer assemblies consisting of a series of stainless steel tubular modules (top hats) connected by a plenum to water boxes. The top hats are constructed from two concentric, rolled perforated plates. The openings in the perforated plate are 3/32 inch diameter nominal. Sandwiched between the concentric tubes of each top-hat module is a bypass eliminator, fabricated from fine knitted wire. This component is designed to further filter fine entrained debris that has already penetrated the perforated top-hat exterior. The RHR/CSS recirculation lines are connected to the main plenum of the strainer assembly using 18-inch piping. Horizontal vortex suppressors are installed above the top-hat strainer assemblies.

- The modified sump structures are nuclear safety-related assemblies designed to withstand safe shutdown earthquake loadings and protected from tornado missiles by virtue of being located within the containment building, which is in turn, protected by the seismically designed reactor building. These structures are passive assemblies qualified for all design environmental conditions in the sump.

The objective of the new strainer design is to provide acceptable flow with minimal head loss at the specified debris loads and to ensure adequate NPSH to the RHR/CSS pumps during the post-LOCA recirculation phase. The new strainer offers approximately 1700 square feet of surface area versus the original 135 square feet total for the original sump screens.

FINAL NRC STAFF CONCLUSION:

The licensee has provided information necessary for the NRC staff review. Based on its review the NRC staff finds the licensee has provided sufficient information as required by GL 2004-02, and 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.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through April 30, 2008.

The NRC staff review of Sump Structural Analysis, has led to the conclusion that the licensee did not adequately addressed the information requested by the revised content guide for GL 2004-02 Item 2(d)(vii). Specifically, the licensee has not provided a summary of the structural qualification design margins for the various components of the sump strainer structural assembly. This information is explicitly requested by the second bullet of the Sump

Structural Analysis Section of the revised content guide. The remainder of the evaluation is relatively well-documented and complete; however, without conveyance of the existing margins between actual stress and allowable stress, it was not possible for the NRC staff to evaluate the extent of the conservatism inherent to the design.

The licensee's submittal stated that structural analyses were performed for the various replacement sump strainer components. The analytical models were subjected to load combinations associated with dead load, operating loads, differential pressure loads, seismic loads (including hydrodynamic mass), and thermal loads. These individual loads are consistent with the guidance of NEI 04-07 and the NRC staff's corresponding SE. The maximum stresses, which were calculated for the analytical models were then compared with the appropriate allowable stresses from the American Institute of Steel Construction (AISC) Manual (AISC 9^{th} Edition) and the American Society of Mechanical Engineers (ASME) Section IIII, Division 1, NF-3324.6 for stainless steel studs/bolts. The welds associated with the stainless steel assembly were qualified from the American Welding Society (AWS) D1.6 guidance. The licensee stated that all design aspects of the replacement sump structure met AISC, AWS, and ASME Boiler and Pressure Vessel Code (ASME Code) allowable stresses.

With regard to potential loadings associated with a HELB, the licensee stated that a postulated HELB, which could potentially interact with the modified ECCS containment sump strainer, were evaluated in accordance with McGuire's current licensing basis. Based upon the new locations of the modified strainers, one interaction was identified at each unit. To address this, regulatory commitments were made to install pipe rupture restraints on the RHR system of each unit. Since appropriate pipe restraints have been installed to protect the sump strainer, the NRC staff finds this acceptable.

The licensee's submittal stated that backflushing was not considered feasible for the replacement sump strainer.

The information provided by the licensee shows that the sump structural evaluation contains inherent conservatism by complying with the AISC 9^{th} Edition, ASME Code, and AWS Welding Code. The licensee did not, however, transmit the interaction ratios or design margins associated with the structural analysis to the NRC staff (see RAI section below). The design inputs, which were tabulated in the submittal, appear reasonable, but without the interaction ratios or design margins, it is not possible for the staff to comment on the level of significance of the conservatism, which has been employed.

The licensee's submittal contained a blanket statement that all components associated with the new strainer assembly meet the applicable AISC, AWS, and ASME Code allowable stresses. The NRC staff proposed an RAI for completeness and comparison to the degree of rigor, which was employed in other review areas.

<u>RAI-30</u>:

> The revised "Content Guide for Generic Letter 2004-02 Supplemental Responses," sent by letter dated November 21, 2007, Section 3k, requests a summary of structural qualification design margins for the various components of the sump strainer structural assembly. This summary should include interaction

ratios and/or design margins for structural members, welds, concrete anchorages, and connection bolts as applicable. Please provide this information.

FINAL NRC STAFF REVIEW:

The NRC final staff review is based on the licensee's July 2, 2012, RAI response.

RAI-30 requested the licensee to provide the design margins for the strainer components, which were analyzed for structural adequacy in support of the McGuire GL 2004-02 resolution. The response to this RAI is documented in the licensee's July 2, 2012, submittal. A figure of the modified sump strainer assembly at McGuire is provided to assist in visualizing the components included in the structural analysis. Additionally, the licensee provided a table summarizing the design inputs and loads used in the structural qualification of the McGuire sump strainer assemblies. The results of the structural analysis performed for the McGuire sump strainer assemblies, including interaction ratios and design margins, are documented in Tables 30S-1 through 30S-11. The maximum stresses and loads, which were calculated for these components are compared with the appropriate allowable stresses from the AISC 9^{th} Edition and the ASME Section IIII, Division 1, NF-3324.6 for stainless steel studs/bolts. The welds associated with the stainless steel assembly were qualified based on the guidance in AWS D1.6.

FINAL NRC STAFF CONCLUSION:

The NRC staff has reviewed the licensee's response to RAI-30 and considers the response to be acceptable. This acceptance is based on the fact that the licensee has presented a detailed set of results for the structural qualification of the components, which make up the McGuire sump strainer assemblies. Based on these results, the licensee was able to demonstrate that all applicable design code requirements were satisfied by maintaining interaction ratios, stresses and loads less than allowable values. This provides the NRC staff with reasonable assurance that the sump strainer assemblies will remain structurally adequate under normal and abnormal loading conditions such that the assemblies will be able to perform their intended design functions. 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 flowpaths upstream of the containment sump for holdup of inventory, which could reduce flow to the sump.

FINAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through April 30, 2008.

The evaluation of post-accident ECCS sump inventory holdup in the McGuire containments includes physical diversions (e.g., curbs and filled CS piping) as well as potential debris blockage. The minimum ECCS sump pool level to ensure strainer submergence for SBLOCA events is discussed in the licensee response, including the assumptions for lost inventory due to physical diversions. The potential loss of ECCS sump inventory due to debris blockage is addressed below.

The lower containment at McGuire is basically made up of two compartments, the area inside the crane wall and the pipe chase. These two areas are connected at lower elevations by a number of crane wall penetrations on each unit, ranging in diameter up to 12 inches. Many of these penetrations are above the floor. Although it is possible for some of these penetrations to clog with debris, it is unlikely that a sufficient number of the penetrations would become clogged sufficiently to create a situation where the ECCS sump could be starved. The CFD model used for the evaluation of debris transport (discussed in detail in Section 3(e) of Enclosure 2) provides the basis for this engineering judgment.

Other potential choke points include the ice condenser drain lines and the refueling canal drains. McGuire has a total of twenty 12-inch diameter ice condenser drain lines for draining the melting ice. If one of these drains were to become clogged, the water would flow to the other drains. It is not likely that all 20 drains would become sufficiently clogged with debris to keep the water from flowing to the containment sump pool. The refueling canal in each unit has six 8-inch drains that are open during operation. Four of the drains discharge inside the crane wall, and the other two discharge into the pipe chase. The plant was designed so that the majority of the upper containment spray water flows to lower containment through these six drains. Given the size of these drains and the debris postulated to be washed down with the sprays (latent debris, paint chips and/or particulate, and possibly a small quantity of LOCA generated fines blown past the ice baskets) these drains are not likely to become clogged.

Finally, the McGuire debris generation calculation does not postulate significant amounts of debris being generated in upper containment, since this area is outside the limiting break ZOI.

McGuire TS SR 3.5.2.8 requires that the ECCS sump be visually inspected to verify there are no restrictions as a result of debris, and no evidence of structural distress or abnormal corrosion present prior to declaring the ECCS sump operable. A visual inspection of containment is performed to ensure no loose material is present, which could be transported to the containment sump and cause restriction of the ECCS pump suction during accident conditions prior to the transition from Mode 5 to Mode 4 operations. When these inspections are performed, major outage work is complete, and any remaining loose material in containment must be logged and tracked in accordance with station procedures for control and accountability. If any debris, damage or deficiency were to be discovered during the inspection, station processes require entry into the corrective action program, with the requisite investigation and implementation of appropriate corrective action prior to the transition from Mode 5 to Mode 4.

McGuire TS 3.6.15 applies to the ice condenser drains and the refueling canal drains. An inspection of the refueling canal drain is required to ensure that each canal drain valve is locked open and each drain is not obstructed by debris prior to entering Mode 4 from Mode 5 after partial/complete fill of the canal. A visual inspection is performed every 92 days to verify that no debris is present in the upper compartment or refueling canal that could obstruct the refueling canal drains. Lastly, each ice condenser floor drain valve is visually inspected and physically tested every 18 months to ensure it is not impaired by ice, frost, or debris; the valve seat shows no evidence of damage; the valve opening force is not excessive; and the drain from the ice condenser floor to the lower compartment is unrestricted.

An additional mitigative measure was taken on the McGuire refueling canal bottom drains to reduce the potential for a choke point at these locations. A perforated plate that existed on the bottom drain in the deep end of the refueling canal was removed for both McGuire units. These modifications are also identified in Section 3(j), item 3(j)(2) of Enclosure 2.

FINAL 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. Since the licensee has shown that the drainage paths from the ice condensers and refueling canal cannot credibly become blocked, the NRC staff concluded that the upstream effects area has been adequately addressed by the licensee. 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 April 30, 2008.

Initially, the licensee evaluated the downstream effects of sump debris on McGuire components and systems in accordance with TR-WCAP-16406-P, Revision 0, dated June 2005 that was superseded by Revision 1 of TR-WCAP-16406-P and the NRC SE for that WCAP. The licensee stated that a comparative evaluation would be performed to address any differences extended by TR-WCAP-16406-P, Revision 1. The licensee stated that the conclusions of the evaluations, based on the original TR-WCAP-16406-P, Revision 0, were considered conservative.

In the April 30, 2008, supplement, the licensee submitted the results of the reevaluation of downstream effects using the methods and acceptance criteria described in TR WCAP 16406 P, Revision 1, and the associated NRC SE. The licensee stated that the reevaluation determined that all affected single and multistage pumps, heat exchangers, instrument tubing, valves, spray nozzles and orifices are not expected to fail or become blocked during the 30-day mission time following a LOCA event. The wear evaluation of all ECCS and CSS piping containing recirculated containment sump pool fluid during and after an accident determined that system piping is not expected to fail. The licensee stated that consistent with the GL 2004-02 supplemental response dated February 28, 2008, the results of the McGuire downstream debris effects evaluations on the critical ECCS/CSS components, performed in accordance with TR-WCAP-16406-P, Revision 1 criteria and the associated NRC SE, demonstrate that the currently installed components are acceptable for the expected ECCS mission time. No design or operational changes are required.

The NRC staff reviewed the evaluation results presented in the licensee's GL 2004-02 response. The licensee performed ex-vessel downstream effects calculations and analyses in accordance with the NRC recognized methods prescribed in TR-WCAP-16406-P-A, Revision 1 and the associated NRC SE, including L&C. Therefore, the NRC staff concludes that the downstream effects of debris laden recirculated sump fluid on ex-vessel downstream components and systems have been adequately addressed at McGuire. The NRC staff considers this item 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.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through November 18, 2008.

Initially, the licensee evaluated the in-vessel downstream effects of sump debris on McGuire components and systems in accordance with TR-WCAP-16406-P, Revision 0, dated June 2005 that is superseded by Revision 1 of TR-WCAP-16406-P and the NRC SE for that WCAP. The licensee also cited the analyses contained in TR-WCAP-16793-NP as being applicable to McGuire. The licensee stated that it was aware that the NRC was still evaluating the industry guidance provided by TR-WCAP-16793-NP, and would monitor the status of this evaluation. Based on the results of the plant specific downstream fiber and particulate debris effects evaluations performed, the licensee stated that it did not expect significant changes to their assessment as a result of the guidance in the final TR-WCAP-16793-NP.

In the letter dated February 28, 2008, the licensee stated that it performed an evaluation of the downstream effects of post-accident containment sump pool debris on the McGuire ECCS/CS systems. The evaluation considered the effect of debris ingested through the containment sump strainer on ECCS/CS components that are required to operate in the ECCS recirculation mode. The evaluation was based on the methodology developed and documented in Section 9 of TR-WCAP-16406-P, Revision 0, which the NRC did not accept for in-vessel evaluations. The licensee's evaluation of the McGuire reactor vessel internals showed that blockage in the vessel would not occur because the smallest flow clearance in the McGuire reactor vessel internals was much larger than the strainer opening size (1.5-inch flow passage vs. 0.09375 inch strainer holes size). Using sump strainer fiber bypass test data, the licensee performed a preliminarily evaluation of the potential for blockage of the nuclear fuel assemblies during containment sump recirculation. The licensee evaluation stated that because the McGuire ECCS strainer top hat design features a debris bypass eliminator, designed to reduce both the fibrous debris size and quantity that could potentially enter the core, the majority of the fiber bypass (over 98 percent) through the debris bypass eliminator would not build a fiber bed below or above the nuclear reactor core. Therefore, per the licensee's evaluation, sufficient open flow paths would exist to allow cooling of the nuclear fuel assemblies.

The licensee stated that the plant-specific fibrous debris bypass evaluations performed for McGuire are bounded by the evaluations described by TR-WCAP-16793-NP. Further, the licensee stated that it was aware that NRC staff was still evaluating the industry guidance provided by TR-WCAP-16793-NP, and will monitor the status of this evaluation. Based on the results of the licensee's specific downstream fiber and particulate debris effects evaluations performed, the licensee stated that significant changes to the current assessment of the McGuire ECCS were not expected.

In the April 30, 2008, supplement, the licensee reaffirmed that the previous acceptable downstream effects evaluations addressing the nuclear fuel and reactor internals were determined to still be bounding with respect to the new requirements of TR-WCAP-16406-P, Revision 1.

The licensee's GL 2004-02 supplemental response for McGuire did not contain sufficient information regarding the size and quantity of bypassed debris to permit a comprehensive evaluation, nor did it specifically address the evaluation guidelines in WCAP 16793-NP. Therefore, the following RAI was generated.

RAI-31:

> The NRC staff considers in-vessel downstream effects to not be fully addressed at McGuire, as well as at other pressurized-water reactors. The supplemental response for McGuire refers to the evaluation methods of Section 9 of Topical Report (TR) WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GS-191," for in-vessel downstream evaluations and makes reference to a comparison of plant-specific parameters to those evaluated in TR WCAP-16793-NP, Revision 0, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final SE for TR WCAP-16793-NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for McGuire by showing that the licensee's plant conditions are bounded by the final TR WCAP-16793-NP and the conditions and limitations identified in the final NRC staff's SE. The licensee may also resolve this item by demonstrating without reference to TR WCAP-16793 or the NRC staff's SE that in-vessel downstream effects have been addressed at McGuire. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff's SE on TR WCAP-16793.

In the November 18, 2008, response, the licensee confirmed that it would address in-vessel downstream effects within 90 days of issuance of the NRC staff's SE on TR-WCAP-16793.

FINAL NRC STAFF REVIEW:

The final NRC staff review is based on the licensee's July 31, 2013, letter.

On April 8, 2013 (ADAMS Accession No. ML13084A152), the NRC staff issued an SE on TR-WCAP-16793-NP, Revision 2, finding it an acceptable model for assessing the effect of sump strainer bypassed fibrous, particulate, and chemical debris on core cooling in PWRs. The TR guidance and acceptance bases were developed through analyses and flow testing using representative fuel assemblies and ECCS flow rates. In order to demonstrate adequate core cooling capability to NRC staff, the TR, the L&C section of the NRC SE of the TR and GL 2004-02 response content guide (ADAMS Accession No. ML073110278) require certain actions of the licensees. Further, the Commission, in SECY-12-0093, provided flexibility to licensees for resolving the issues identified in GSI-191, by allowing several methods, including the deterministic method (identified as Option 1 in the SECY) to demonstrate adequate core cooling. For the in-vessel downstream effects evaluation, the licensee elected to pursue Option 1 and, therefore, follow TR-WCAP-16793-NP-A, Revision 2.

The GL 2004-02 response content guide required the response to item n, "Downstream Effects - Fuel and Vessel" to confirm that the licensee's evaluation is consistent with, or bounded by, the industry generic guidance contained in TR-WCAP-16793-NP, Revision 2, as modified by the NRC staff's L&C stated in the NRC safety evaluation on that document. Also, the response should briefly summarize the application of the WCAP evaluation methods and include the following information:

- The available driving head and ECCS flow rate used in the evaluation of the hot-leg break LOCA scenario,
- The type(s) of fuel and inlet filters installed in the plant,
- The results of the peak clad temperature and clad deposit thickness (LOCADM) calculation,
- The amount of fiber (in grams per fuel assembly) that is assumed to reach the core inlet after a LOCA and,
- The method(s) used to estimate the quantity and size distribution of the fibrous debris that would pass through the ECCS sump strainer and reach the core inlet during a LOCA.

The L&C section of the NRC SE of WCAP-16793-NP, Revision 2 states that licensees may determine the quantity of debris that passes through their strainers by (1) performing strainer bypass testing using the plant strainer design, plant-specific debris loads, and plant-specific flow velocities; (2) relying on strainer bypass values developed through strainer bypass testing of the same vendor and same perforation size, prorated to the licensee's plant-specific strainer area; approach velocity; debris types, and debris quantities; or (3) assuming that the entire quantity of fiber transported to the sump strainer passes through the sump strainer. When applying the above criteria, the licensee shall ensure that the width of any gaps in the strainer assembly does not exceed the diameter of the strainer perforations and the total area of the gaps does not exceed 1 percent of the total strainer perforation area.

In the licensee's July 31, 2013, response to NRC staff RAI regarding in-vessel downstream effects, the licensee provided the following information:

- The strainers are of the "top hat" design, consisting of two concentric cylinders having 3/32 of an inch perforations and stainless steel knitted wire mesh located in the annular space between the two cylinders, functioning as a debris bypass eliminator. Strainer bypass-testing performed by Alion Science and Technology yielded a bounding fiber bypass quantity of 8.3 grams per fuel assembly—well below the 15 gram per fuel assembly limit qualified by TR-WCAP-16793-NP-A, Revision 2.

- The calculated maximum fuel clad temperature (after the initial quench) is 350 degree F and the maximum calculated deposit thickness on the fuel rods is 12.2 thousandths of an inch (mils) well below the WCAP limits of 800 degree F and 50 mils thickness.

- In the July 31, 2013, letter, the licensee satisfactorily demonstrated compliance with the 14 L&C of the NRC SE of TR-WCAP-16793-NP-A, Revision 2.

FINAL NRC STAFF CONCLUSION:

The NRC staff reviewed the description of the analyses, strainer bypass testing, and compliance with the L&C of the SE, as described in the Licensee's GL-2004-02 response to Item (n) and finds that the licensee's response addressing in-vessel downstream effects for McGuire satisfies the requirements stated in TR WCAP-16793-NP-A, Revision 2 and the NRC SE of that document. Therefore, the NRC staff concludes that the licensee has adequately addressed the potential effects of ECCS sump strainer-bypassed debris on core cooling at McGuire. The NRC staff considers this item 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.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through April 30, 2008.

The licensee performed bench testing to evaluate aluminum corrosion rates in representative post-LOCA sump pool environments. The NRC staff reviewed the bench tests results (for information only outside the GL supplement review) and concluded the tests were well conceived and executed. The licensee used these test results to establish a licensee specific aluminum release rate algorithm. Since the licensee's aluminum release is different and slightly greater than that calculated using the WCAP-16530-NP equation, the licensee used their own aluminum release rate calculations.

The licensee also performed 14 vertical loop head loss tests to evaluate sensitivities for potential chemical effects. Since the licensee is relying on the IPT, details of the vertical loop head loss tests were not provided in the licensee submittal.

The licensee performed a 30 day IPT that involved adding nonchemical debris such as fiberglass to a test tank containing heated borated water with sodium tetraborate added to reach a plant specific pH. Dissolved aluminum, in the form of aluminum nitrate, was metered into the tank over the course of the test. Aluminum concentrations were intended to match the aluminum concentration predicted by the release rate calculations. The test fluid was heated and the tank temperature was highest at the start of the test and allowed to cool during the test to simulate the post-LOCA cooling profile.

IPT used maximum temperature profile for the beginning of the test and the minimum temperature profile at the end of the test to promote dissolution and subsequent precipitation. A bounding amount of aluminum was used for the submerged and sprayed surface areas.

Due to the tank/pipe/strainer physical arrangement, the plant debris would not transport to the top hat strainer using the normal test flow. Therefore, a reduced water volume, more turbulent flow was used during debris addition in an attempt to transport the debris to the strainer. Video of the debris addition to the test tank showed significant debris agglomeration (e.g., clumps of debris dropping from the bucket into the tank). Following the test, the NRC staff observed that a significant amount of fibrous debris settled at the entrance to the pipe section, upstream of the test strainer.

The NRC staff was concerned that the debris bed that formed on the test strainer, and the amount of bare strainer area, is not representative of what may occur with the plant configuration. Dissolved aluminum in the licensee's 30 IPT decreased over time, which may indicate a precipitation process. NRC sponsored tests (at higher pH) indicated that aluminum based precipitate formation in a sodium tetraborate environment most probably occurs in a delayed time frame rather than immediately.

<u>INITIAL NRC STAFF CONCLUSION</u>:

For this review area the licensee has not provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Provide a summary-level basis for this overall conclusion.

Although the licensee's integrated head loss testing (i.e., IPT) indicated that the pressure drop across the strainer was acceptable, NRC staff observations of the test and video review of debris addition has caused the staff to question whether this test was representative of the plant. Fibrous debris was agglomerated when added to the test tank and flow to a single 36-inch long Enercon top hat strainer was intentionally turbulent in an attempt to transport the fiber. This flow during debris addition was not prototypical of the plant and therefore, the debris bed on the top hat strainer may not have been prototypical. At the completion of the test, approximately 10 inches at the top of the strainer were bare, so any impact from chemical precipitate was not necessarily measured since precipitate tends to pass through bare strainer.

<u>RAI-32</u>:

> Please discuss why the Integrated Prototype Test (IPT) provided a representative debris bed on the top-hat strainer module for filtering chemical precipitates. The NRC staff observed the debris addition video and concluded that the fibrous debris introduced into the test tank was more agglomerated than what may arrive at the strainer under post-LOCA flow conditions in the plant. Please discuss whether the amount of bare strainer area observed in the test representative of what is expected to occur with the plant strainer array if a LBLOCA were to occur. The use of chemical effects test results derived from a test which formed a non-prototypically partially clean screen fiber bed would not be appropriate.

The NRC staff asked this RAI because the previous strainer head loss test performed by the licensee at Wyle Laboratory that evaluated chemical effects had issues with debris preparation, debris agglomeration, and debris transport to the test strainer. Therefore, the NRC staff questioned whether the licensee had an adequate test for chemical effects since the staff concluded that the amount of bare strainer area in the test may have been nonconservative.

FINAL NRC STAFF EVALUATION:

The final NRC staff review is based on the licensee's July 2, 2012, RAI response.

NRC Staff Evaluation of RAI-32 Response:

As stated in the licensee's July 2, 2012, response, the RAI based on the licensee's February 28, 2008, response (and supplemented with a April 30, 2008, response), no longer applies in the same manner as written since the licensee redesigned the test facility and performed additional testing in response to the RAI. Nevertheless, the broad intent of the question that related to the licensee demonstrating an adequate chemical effects evaluation remained valid.

The licensee calculated total head loss by adding the chemical head loss to the head loss from other (nonchemical) debris from a strainer test performed at Wyle Laboratory. Chemical effects were simulated by adding WCAP-16530-NP-A precipitate, assuming a delay in the precipitate formation until the post-LOCA pool temperature cools to approximately 156 degree F. This temperature would be reached between approximately 16 hours (160 degree F) and 1.2 days (140 degree F) following swap-over to sump recirculation phase.

The NRC staff evaluated the licensee's response on delayed precipitation based on plant specific pH, temperature, and calculated aluminum concentration in the post-LOCA sump pool. In the licensee's February 28, 2008, supplement, it stated that McGuire uses sodium tetraborate to buffer the post-LOCA pool pH. The McGuire pH is calculated to be in the approximate range of 7.8 to 8.0. The licensee's aluminum concentration provided in the same submittal is less than 5 parts per million. Using this information, the NRC staff calculated the solubility of aluminum using the referenced Argonne National Laboratory (ANL) Technical Letter Report "Aluminum Solubility in Boron Containing Solutions as a Function of pH and Temperature," September 19, 2008 (ADAMS Accession No. ML091610696), Equation 4 and confirmed that the licensee's dissolved aluminum concentration is well below the amount predicted to result in precipitation at the 156 degree F temperature of interest. In addition, though not all test parameters were identical, the aluminum solubility observed in Integrated Chemical Effects Test 5 also supports the NRC staff judgment that the McGuire assumption on precipitation temperature is conservative. These tests were conducted and reported in NUREG/CR-6914, "Integrated Chemical Effects Test Project," December 2006. Therefore, the licensee's overall evaluation is acceptable to the NRC staff since the use of chemical precipitate formed per the TR-WCAP-16530-NP-A in strainer head loss testing is acceptable and the delay in applying the chemical induced head loss according to the McGuire evaluation also, is acceptable.

FINAL 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. The licensee has provided information such that the reviewer has high confidence in the adequacy of the licensee's test and evaluation methods in this subject area.

The licensee performed sump strainer testing and simulated chemical effects by adding premixed precipitate formed with the TR-WCAP-16530-NP-A method. This is acceptable to the NRC staff since the NRC staff reviewed and approved this WCAP method for evaluating chemical effects. Since the plant specific approach credited short term solubility of aluminum based precipitates, the staff performed an independent calculation of aluminum solubility using Equation 4 in the referenced ANL Technical Letter Report. The NRC staff calculation showed the licensee assumption about precipitation temperature to be conservative and therefore, acceptable to the NRC staff. Based on the above NRC staff review, the NRC staff concludes that the McGuire chemical effects evaluation is acceptable. Therefore, the NRC staff considers this item 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.

In supplemented response letter dated February 28, 2008, the licensee committed to change the UFSAR in accordance with 10 CFR 50.71(e) to reflect the changes to the plant in support of the resolution to GL 2004-02. In addition, the licensee stated that changes would be made to the UFSAR describing the new licensing basis to reflect the revised debris loading as it affects ECCS sump strainer performance and in-vessel effects, including the following:

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

FINAL 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 effect the appropriate changes to the McGuire 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 all 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 the potential foe debris to adversely affect long term core cooling. The NRC staff finds the information provided by the licensee demonstrates that debris will not inhibit the ECCS or CSS performance of its intended function in accordance 10 CFR 50.46 to assure adequate long term core cooling following a design basis accident.

Therefore, the NRC staff finds the licensee’s responses to GL-2004-04 are adequate and considers GL-2004-02 closed for McGuire.