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

September 24, 2021

Mr. Daniel G. Stoddard
Senior Vice President, Generation
and Chief Nuclear Officer
South Carolina Eclectic and Gas Company
Virgil C. Summer Nuclear Station
Innsbrook Technical Center
5000 Dominion Blvd.
Glen Allen, VA 23060-6711

SUBJECT: VIRGIL C. SUMMER NUCLEAR STATION, UNIT 1 – CLOSEOUT OF GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (EPID L-2017-LRC-0000)

Dear Mr. Stoddard:

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

By letter dated May 14, 2013 (ADAMS Accession No. ML13140A007), South Carolina Electric and Gas andElecric Company (the licensee) stated that they will pursue Option 2 (deterministic) for the closure of GSI-191 and GL 2004-02 for Virgil C. Summer Nuclear Station Unit 1 (Summer).

On July 23, 2019 (ADAMS Package Accession No. ML19203A303), GSI-191 was closed. It was determined that the technical issues identified in GSI-191 were now well understood, and therefore, GSI-191 could be closed. Prior to and in support of closing GSI-191, the NRC staff issued a technical evaluation report on in-vessel downstream effects (ADAMS Accession Nos. ML19178A252 and ML19073A044 (not publicly available, proprietary information)). Following the closure of GSI-191, the NRC staff also issued the review guidance for in-vessel downstream effects, "NRC Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of Generic Letter 2004-02 Responses" (ADAMS Accession No. ML19228A011dated September 9, 2019), to support review of the GL 2004-02 responses.

The NRC staff has reviewed the licensee's responses and supplements associated with GL 2004-02. Based on the evaluations, the NRC staff finds the licensee has provided adequate information as requested by GL 2004-02.

The stated purpose of GL 2004-02 was focused on demonstrating compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.46. Specifically, GL 2004-02 requested addressees to perform an evaluation of the emergency core cooling system (ECCS) and containment spray system (CSS) recirculation and, if necessary, take additional action to ensure system function considering the potential for debris to adversely affect long-term core cooling. The NRC staff finds the information provided by the licensee demonstrates that debris will not inhibit the ECCS or CSS performance following a postulated loss-of-coolant accident. Therefore, the ability of the systems to perform their safety functions, to assure adequate long-term core cooling following a design-basis accident, as required by 10 CFR 50.46, has been demonstrated.

Based on its review, the NRC staff finds the licensee's responses to GL 2004-02 are adequate and considers GL 2004-02 closed for Summer.

Enclosed is the summary of the NRC staff's review. If you have any questions, please contact me at 301-415-2481 or via e-mail at Ed.Miller@nrc.gov.

Sincerely,

/RA/

G. Edward Miller, Project Manager
Plant Licensing Branch II-I
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-395

Enclosure:
NRC Staff Review of GL 2004-02
for Summer

cc: Listserv

UNITED STATES
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U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF THE DOCUMENTATION PROVIDED BY SOUTH CAROLINA ELECTRIC & GAS COMPANY FOR VIRGIL C. SUMMER NUCLEAR STATION UNIT 1 DOCKET NO. 50-395 CONCERNING RESOLUTION OF GENERIC LETTER 2004-02 POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN-BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

1.0 INTRODUCTION

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

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

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

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

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

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

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

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

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

By letter dated May 28, 2004 (ADAMS Accession No. ML041550661), the Nuclear Energy Institute (NEI) submitted a report describing a methodology for use by PWRs in the evaluation of containment sump performance. NEI requested that the NRC review the methodology. The methodology was intended to allow 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 Accession No. ML043280641), the NRC staff issued an evaluation of the NEI methodology. The NRC staff concluded that the methodology, as approved in accordance with the NRC staff safety evaluation (SE), provides an acceptable overall guidance methodology for the plant-specific evaluation of the ECCS or CSS sump performance following postulated DBAs.

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

- TR-WCAP-16406-P-A, “Evaluation of Downstream Sump Debris Effects in Support of GSI-191,” Revision 1 (not publicly available), to address the effects of debris on piping systems and components (SE at ADAMS Accession No. ML073520295).

- 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), to provide a consistent approach for plants to evaluate the chemical effects that may occur post-accident in containment sump fluids (SE at ADAMS Accession No. ML073521072).

- TR-WCAP-16793-NP-A, “Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid,” Revision 2 issued July 2013 (ADAMS Accession No. ML13239A114), to address the effects of debris on the reactor core (SE at ADAMS Accession No. ML13084A154).

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

After the NRC staff evaluated licensee responses to GL 2004-02, the NRC staff found that there was a misunderstanding between the industry and the NRC on the level of detail necessary to respond to GL 2004-02. The NRC staff in concert with stakeholders developed a content guide for responding to requests for additional information (RAIs) concerning GL 2004-02. By letter dated August 15, 2007 (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 DBA. By letter dated November 21, 2007 (ADAMS Accession No. ML073110389), the NRC issued a revised content guide.

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

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

Based on the interactions with stakeholders and the results of the industry testing, the NRC staff, in 2012, developed three options to resolve GSI-191. These options were documented and proposed to the Commission in SECY-12-0093, "Closure Options for Generic Safety Issue - 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance," dated July 9, 2012 (ADAMS Accession No. ML121320270). 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. Most of the plants closing under this option are low fiber plants with less than 15 grams of fiber per fuel assembly.

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

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

  - Option 2 Risk Informed: use of risk informed analysis to demonstrate adequate long term core cooling, e.g., South Texas Project (ADAMS Package Accession No. ML17019A001).

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

The options allowed industry alternative approaches for resolving GSI-191. The Commission issued a Staff Requirement Memorandum (SRM-SECY-0093) on December 14, 2012 (ADAMS Accession No. ML12349A378), approving all three options for closure of GSI-191.

By letter dated May 16, 2013 (ADAMS Accession No. ML13140A007), South Carolina Electric & Gas Company (the licensee) stated that they will pursue Option 2 (deterministic) for the closure of GSI-191 and GL 2004-02 for Virgil C. Summer Nuclear Station Unit 1 (Summer).

On July 23, 2019 (ADAMS Package Accession No. ML19203A303), Generic Issue (GI)-191 was closed. It was determined that the technical issues identified in GI-191 were now well understood and therefore GI-191 could be closed. Prior to and in support of closing the GI, NRC staff issued a technical evaluation report on in-vessel downstream effects (IVDEs) (ADAMS Accession Nos. ML19178A252 and ML19073A044 (non-public version)). Following the closure of the GI, NRC staff also issued review guidance for IVDEs to support review of the GL 2004-02 responses “NRC Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of Generic Letter 2004-02 Responses” (ADAMS Accession No. ML19228A011).

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	DOCUMENT
March 7, 2005	ML050690207	Initial Response to GL
September 1, 2005	ML052520333	Supplemental Information
February 8, 2006	ML060410214	Supplemental Information
February 21, 2006	ML060380003	1st NRC RAI
February 29, 2008	ML080640545	Licensee Response to RAI
September 9, 2008	ML082590346	Supplemental Information
February 3, 2009	ML090270927	2nd NRC RAI
November 29, 2009	ML093360336	Licensee Response to RAI
December 17, 2010	ML103610171	Licensee Response to RAI
May 16, 2013	ML13140A007	Supplemental Information
June 17, 2021	ML21168A261	Final Response

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

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

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

- Evaluation of sump performance using the guidance of NEI 04-07.
- Downstream effects evaluation using the TR-WCAP-16406-P-A, Revision 1 methodology.
- Containment walkdowns using the guidance of NEI 02-01, “Condition Assessment Guidelines: Debris Sources Inside PWR Containments,” April 19, 2002 (ADAMS Accession No. ML021490241).
- The modification process and maintenance process have been enhanced relative to GL 2004-02 controls to ensure operability of the containment sumps and control the amount of insulation in containment.
- Installation of vertical trash racks to prevent large debris from reaching the strainer.
- Installing modifications to prevent high velocity streams of water from approaching the strainer.
- Replacement of twelve high head safety injection (HHSI) throttle valves with Flowserve Pressure-Combo valves.
- Installation of a new ECCS sump strainer in Summer Unit 1 (≈ 2,939 and 2,380 square feet (ft^2) available flow area for Sump A and Sump B respectively).
- ECCS sump strainer performance for Summer Unit 1 was confirmed by performing prototype chemical precipitate head loss tests.
- Latent debris sampling completed which established a 105-pound (lb) load that includes a 50 percent margin.
- Submitted license amendment request (LAR) and received amendment for alternate source term (AST) LOCA dose analysis to address concerns with pump seal backup bushing failures.
- Established programs to track the quantities of coatings that may contribute to the debris source term.

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 sizes and locations that present the greatest challenge to post-accident sump performance. The term ZOI used in this section refers to the spherical zone representing the volume of space affected by the ruptured piping as it relates to specific materials. Different materials have different ZOIs based on their fragility.

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through May 16, 2013. The guidance documents used for the review include the Revised Content Guide dated November 2007, Regulatory Guide (RG) 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident", (ADAMS Accession No. ML033140347) and the NEI 04-07 guidance report (ADAMS Accession No. 050550138), and associated NRC staff SE (GR/SE) (ADAMS Accession No. ML050550156).

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

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

The licensee evaluated break locations using civil and mechanical drawings and dividing the reactor building into zones defined by physical barriers. The volume of insulation within each zone was quantified in a spreadsheet. The break specific results were then evaluated according to the amount and type of insulation in each zone.

The licensees determined that there are four possible break locations that have potential to generate the limiting debris source term. These breaks include:

1. RCS crossover leg pipe (31") break at the SG outlet.
2. Pressurizer safety relief line (6") break.
3. Pressurizer surge line (14") break below the pressurizer.
4. Reactor vessel nozzle break.

The ECCS in recirculation mode is not required for secondary side breaks. Therefore, secondary side breaks were not considered in the break selection evaluation.

RAI REVIEW:

There was one RAI related to break selection. The licensee was asked to identify which reactor coolant loop was used to evaluate the postulated crossover leg break and describe how it was ensured that the break selection maximized the generation of Temp-Mat debris. The licensee's response was that all three reactor coolant loops were evaluated in the debris generation process. Loop “A” was used to evaluate the postulated crossover leg break as this loop resulted in the greatest amount of destroyed Temp-Mat. Loops “B” and “C” were bounded by the quantity of debris in Loop “A”.

Because the licensee evaluated all three loops and chose the location with the highest generation of Temp-Mat debris, the NRC staff concludes that the RAI was addressed adequately.

NRC STAFF CONCLUSION:

For this review area, the licensee has provided sufficient information such that the NRC staff has reasonable assurance that it has been addressed conservatively or prototypically. The break location analysis completed by the licensee is in accordance with the content guide and the GR/SE and used acceptable methods to determine break locations to analyze for limiting debris generation. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02.

4.0 DEBRIS GENERATION/ZONE OF INFLUENCE (EXCLUDING COATINGS)

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through November 29, 2009.

The NRC staff found that the Summer debris generation evaluation generally followed approved guidance. Reflective metal insulation (RMI), Temp-Mat, Marinite XL, Kaowool and Kaowool M-Board are predicted to be within the ZOI of postulated breaks. The supplemental response stated that the majority of insulation within the reactor building (RB) is RMI. However, it was unclear that the insulation on the reactor vessel was RMI. The ZOIs selected for the materials were 11.7D for Temp-Mat, 5.45D for Kaowool, 28.6D for Kaowool M-Board, and 28.6D for RMI. Marinite XL is used as insulation in the penetrations through the primary shield wall and on the reactor nozzles. The Marinite XL associated with the RCS line that breaks is considered to be completely destroyed. The ZOIs are per the applicable guidance or conservative.

RAI REVIEW:

On February 3, 2009, the NRC staff issued an RAI requesting that the licensee identify the insulating material(s) installed on the reactor vessel, and if applicable identify any materials other than RMI that are installed on the reactor vessel that could be damaged by potential breaks.

On November 29, 2009, the licensee responded to the NRC staff’s RAI stating that the reactor vessel insulation is comprised of all RMI. The licensee also referenced the debris generation created by a cold-leg nozzle break as having been provided to the NRC staff in a previous supplemental response (licensee letter RC-08-0031, Table 5).

NRC STAFF CONCLUSION:

The NRC staff found that the licensee statement that the reactor vessel insulation is comprised solely of RMI adequately addressed the RAI. The NRC staff concern was that other materials may have been installed on the reactor vessel. The confirmation of the absence of alternate insulating materials is a satisfactory response.

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

5.0 DEBRIS CHARACTERISTICS

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The NRC staff found that the licensee largely provided the information requested in the content guide. The NRC staff considered the licensee's response to be consistent with the approved guidance.

The debris generated by the analyzed limiting LOCAs at Summer may include RMI, Temp-Mat, Kaowool, Marinite XL, coating particulate, coating chips, miscellaneous debris, and latent debris.

RMI debris size was assumed to be distributed as follows:

RMI Debris Size Distribution	
Debris Size (inch)	Percentage of Total Recovered
¼	4.3%
½	20.2%
1	20.9%
2	25.6%
4	16.8%
6	12.2%

The RMI size distribution is based on an NRC test conducted by Siemens reported in NUREG/CR-6808 (ADAMS Accession Nos. ML030780733 and ML030920540) and is conservative for a large 28.6D ZOI.

Temp-Mat was assumed to be distributed as follows:

Temp-Mat Debris Size Distribution Within Each Zone		
	Size 45.0 psi ZOI (3.7 L/D)	10.2 – 45.0 psi ZOI (11.7 – 3.7 L/D)
Fines (Individual Fibers)	20%	7%
Small Pieces (<6" on a Side)	80%	27%
Large Exposed (Uncovered) Pieces	0%	32%
Intact (Covered) Blankets	0%	34%

The Temp-Mat size distribution was based on the methodology in Appendix II to the SE, which used two subzones to determine the debris size distribution.

The licensee assumed that the Marinite XL insulation on the RCS pipe that breaks will be rendered into fine particulate that is 100 percent transportable to the sump.

Kaowool was assumed to be 60 percent small fines and 40 percent large pieces per SE guidance.

In lieu of determining material properties, the licensee assumed a minimum destruction pressure and 100 percent fines for M-Board. Microscopic properties similar to Temp-Mat were assigned. Although the base fibers are different material (ceramic versus glass) and it is unclear why this M-Board wouldn't be modeled simply as Kaowool, the NRC staff concluded the overall treatment of M-Board is conservative.

Miscellaneous debris was handled per the SE guidance as flat sheets. Seventy five (75) percent of this surface area was considered sacrificial strainer area. Unqualified/degraded coatings were generally assumed to be chips. Coatings and latent debris were reviewed separately. The licensee provided densities and characteristic sizes in a table in the supplemental response.

The NRC staff identified significant conservatisms as follows: (1) 100 percent fines for Kaowool M-Board and, (2) conservative treatment of Marinite.

NRC STAFF CONCLUSION:

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

6.0 LATENT DEBRIS

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008. For this area, the NRC staff found that the licensee had provided the information as designated by approved guidance with the exception that the sampling program was not described in adequate detail. Senior NRC staff on the GL 2004-02 Integrated Review Team (IRT) were tasked with weighing conservatism against uncertainty in the licensee's methodology. The latent debris reviewer and the IRT determined that the sampling program contained adequate conservatism such that it was not necessary to request additional information from the licensee on the issue.

The licensee determined that the containment at Summer contains 69.3 lb of latent debris and increased this to 105 lb for conservatism. The licensee assumed that 15 percent of the debris is fibrous and the remaining 85 percent is particulate in accordance with NRC approved guidance.

The NRC staff concluded that the information provided by the licensee was adequate and in accordance with NRC approved guidance.

NRC STAFF CONCLUSION:

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

7.0 DEBRIS TRANSPORT

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through May 16, 2013.

The licensee provided information that was consistent with the content guide. The licensee used computation fluid dynamic (CFD) modeling and debris transport tree analysis to determine debris loading on the strainers. The NRC staff found aspects of the licensee's transport calculation to be conservative. However, the NRC staff determined that several potential nonconservatisms existed, which included paint chip transport, fibrous debris erosion, and the use of transport metrics from NUREG/CR-2982, "Buoyancy, transport, and head loss of fibrous reactor insulation. Rev. 1", July 1983, International Atomic Energy Agency (IAEA).

The licensee considered four main transport modes: blowdown, washdown, pool fill-up, and recirculation.

Blowdown:

Some debris considered to be blown upward. All other debris assumed to be blown to lower containment. Large pieces were assumed to be stopped by gratings and not reach upper containment.

Washdown:

All debris blown to upper containment was conservatively assumed to wash down to the pool.

Pool Fill-Up:

No transport to ECCS sump was assumed during pool fill up because the strainer is surrounded by a 6-inch curb. The licensee assumed 0 percent holdup in inactive volumes.

Recirculation:

The licensee used CFD and nodal analysis to evaluate recirculation transport. The CFD was run for breaks on all 3 cross-over legs to determine the most limiting break location.

The licensee assumed the following conservatisms with regard to debris transport analysis: 100 percent transport for latent and failed coating particulate, 100 percent miscellaneous debris transport, 100 percent fine fiber transport, no inactive pool credit, considered maximum debris transport for each type of debris across each case that was run to determine maximum debris transport fractions, and flowrates used in CFD analysis were conservative.

The licensee used NUREG data to determine transport metrics for fibrous materials and paint chips.

The licensee used proprietary Alion Science and Technology fiberglass erosion test results to justify a reduced erosion rate for fibrous material.

RAI REVIEW:

By letter dated February 3, 2009, the NRC staff requested additional information to complete its review. Specifically, the NRC staff requested additional information regarding the 10 percent erosion assumption for fibrous debris, the methodology used to calculate the tumbling velocity metrics used for paint chips, and the assumptions used for Temp-Mat transport velocity metrics. By letter dated November 29, 2009, the licensee responded to the requests. Based on test data provided by the licensee, the NRC staff determined that the 10 percent erosion assumption is conservative for fibrous debris as justified on a plant specific basis for Summer. The NRC staff also determined the CFD analysis used by the licensee to calculate tumbling velocity metrics used for paint chips to be conservative. Lastly, the licensee revised its previous responses to Temp-Mat velocity metrics and assumed a more conservative tumbling velocity using NUKON for small pieces and Mineral Wool for large pieces. The NRC staff finds these tumbling velocity assumptions adequate. Therefore, the responses to the RAIs are acceptable.

NRC STAFF CONCLUSION:

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

8.0 HEAD LOSS AND VORTEXING

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through May 16, 2013. The guidance documents used for the review include the Revised Content Guide from November 2007 and NEI 04-07 "Pressurized Water Reactor Sump Performance Evaluation Methodology", Volume 2. In order to address the NRC staff questions, the licensee performed additional head loss testing to justify that the values being used in the analysis were adequate.

The licensee's approach to reducing strainer head loss was to install an array of Atomic Energy of Canada, Ltd (AECL) strainer modules in place of the original sump strainers. Summer has two separate sumps, one for each train of ECCS/CS. Scaled testing of the strainer modules was conducted at AECL. The testing did not address chemical effects but concentrated on fibrous and particulate debris predicted to reach the strainer following a postulated LOCA. The licensee determined, based on the non-chemical debris testing that chemical testing is not required due to lack of a fibrous bed. The new strainer modules increase the area of the strainer significantly. The strainer area is about 5,300 ft^2 total with 2,939 ft^2 for the A sump and 2,379 ft^2 for the B sump. The licensee stated that the majority of the insulation debris in containment is RMI. The licensee assumed that there would be 105 lb of latent material within containment of which 15.75 lb would be fine fibers. The licensee assumes 200 ft^2 of sacrificial area for labels, tape, and other miscellaneous debris and subtracted 150 ft^2 from the strainer area when scaling the test parameters.

The AECL strainer design incorporates internal orifices to create relatively uniform flow through all strainer perforated surfaces.

The licensee evaluated strainer submergence under large break LOCA (LBLOCA) and small break LOCA (SBLOCA) conditions at the access hatch and grating elevation. Minimum submergence is 2.67 ft. for the LBLOCA and 1.85 ft. for the SBLOCA. This is measured to the grating that covers the strainers. Submergence of the strainer fins or disks is somewhat greater.

Vortex evaluations were completed for two design considerations: (1) air ingestion to the strainer through an air vent hole and (2) vortex formation at the grating engineered opening. The strainer design at Summer includes 24 vent holes just below the top deck of the strainer closest to the surface of the water. These vent holes were analyzed for vortex ingestion assuming they were not covered by perforated plates. Engineered openings are a design feature provided in the grating surface over each sump to address concerns related to bridging or blocking of the grating horizontal surface. No vortex formation was observed or predicted for either design consideration. During testing, the strainer flow rates were increased to 170 percent of rated flow and no vortex formation occurred.

The mechanical design allowable head loss across the strainers is 4.08 pounds per square inch differential (psid) at 70 degrees Fahrenheit (°F). The calculated clean strainer head loss is 0.009 psi. The debris source term has a high particulate to fiber ratio and testing found that the highest head loss was attained if coatings were assumed to fail as chips. The debris head loss is based on test data. From test data, the bounding head loss is 2.72 psid at accident temperature.

The licensee performed plant-specific head loss testing using full scale strainer fins representative of one bank of fins on the Sump B strainer. Sump B was chosen because it is the smaller of the two strainers resulting in a higher head loss than Sump A for the same quantity of debris. The debris loading and flow was scaled to a strainer surface area of 2,229 ft^2. Three large scale tests were run:

1. High RMI debris load such that the outboard space of the strainer was completely filled with RMI debris.
2. Marinite XL case with all coatings failing as particulate.
3. Marinite XL case with epoxy outside the zone of influence failing in as chips as well as particulate. Note that excess coatings were added to this test. The full unqualified coatings load was added as particulate and more than 1x the full unqualified coatings load was added as chips. The head loss for test 3 below is based on a debris load greater than design. The design basis head loss credited by the licensee is 3.15 psid at 104 °F. This head loss was later reduced slightly based on RIG-89 testing as discussed below.

Conservatisms in the tests include:

1) Head loss testing was performed based on scaling of the smaller of the two strainers.
2) Summer has two separate strainers, one for each train of ECCS/CS. During testing all debris was assumed to transport to a single strainer. Typically, both strainers would be in service, but the testing accounts for the required single failure assumption.
3) The licensee has a relatively small amount of fibrous debris in containment and added 50 percent to the latent debris amount determined by sampling.
4) Because the strainers are located in a sump, minimum submergence is relatively high.

The large scale test program used the full debris load scaled to the test module surface area. The full load of fiber was added to the large scale test. While head loss did increase above the clean strainer head loss, a thin bed did not form and the head loss was within the allowable NPSH margin. This demonstrated the “no thin bed” strainer design.

The licensee did not credit near field settling during testing. The large-scale strainer test simulated the sump pit using baffle plates around the test assembly. All debris was added directly on top of the strainer test module. The particulate debris and fiber was noted not to settle below the strainer fins. The particulate debris circulated through the system. The paint chips that did not adhere to the screen settled to the area below the fins as would be expected in the actual sump pit. The area outside of the baffles was swept to keep material in suspension and promote transport to the strainer.

The licensee performed smaller scale testing, termed RIG-89 testing, to determine the effects of chemical precipitates on strainer head loss. The NRC staff had previously noted that some RIG-89 testing had resulted in non-chemical head losses lower than those observed in the large-scale testing. For Summer, the RIG-89 non-chemical head losses were consistent with those observed in the large-scale tests. Therefore, this issue is not applicable to the licensee’s test program for Summer. The NRC staff found that the RIG-89 testing for Summer was conducted in accordance with NRC guidance. The testing found that the head losses, for the limiting debris loads, were slightly reduced from those determined in the large-scale tests. The

RIG-89 testing confirmed that the test results from earlier testing were valid and that chemical effects were adequately included in the results.

When evaluating flashing across the strainer, the licensee used a full debris load and did not credit containment accident pressure. Saturation is assumed at temperatures of 212 °F and above. Results for pressure drop and level margin for temperatures from 70 °F to 195.5 °F are reported on page 51 of the February 29, 2008, supplement. An updated table is provided in the December 17, 2010, follow up to the supplemental response. As a result of slightly decreased head loss based on updated testing, the margin to flashing is increased. The results show that there is margin to flashing even at high temperatures, therefore, flashing across the sump strainer is not a concern.

<u>RAI REVIEW</u>

There were numerous RAIs regarding head loss and vortexing during the review. The RAIs issued on February 3, 2009, documented the remaining NRC staff concerns. The resolution for the more significant RAIs is noted here. The RIG-89 test facility and test practices were observed by NRC staff and were conducted in accordance with NRC approved guidance. The RAIs were mainly associated with the earlier, large scale testing.

The NRC staff asked several RAIs to gain adequate information to ensure that the test program adequately modeled all of the potential debris loads that could occur at the plant. The NRC staff also asked several questions regarding the test methodology to ensure that the testing was conducted per approved guidance. The licensee provided information such that the NRC staff concluded that these areas were evaluated satisfactorily and in accordance with applicable guidance. The NRC staff notes that even though the licensee was able to answer most of the NRC staff questions regarding these issues satisfactorily the licensee performed additional chemical effects testing (RIG-89) to validate and refine the previous results. The RIG-89 testing was conducted using approved guidance.

The NRC staff asked the licensee to validate that bore holes or bed discontinuities did not invalidate the viscosity correction used to extrapolate the test results to higher temperature conditions and provide any flow sweeps used to identify the flow regime in the debris bed. The licensee response described that they carefully examined the debris bed for boreholes and sudden drops in pressure were not observed in the head loss plots meaning discontinuities were not present during large scale testing. This indicates that boreholes were not present and flow through the debris bed was laminar. Photographs of the debris bed were reviewed by the NRC staff to further validate discontinuities were not present. In addition, the licensee performed flow sweeps during the RIG-89 testing for chemical effects. These flow sweeps provided data that justified that a viscosity correction could be applied per NRC guidance.

The NRC staff requested information to determine whether the large-scale test results reported were adequately adjusted to account for additional head loss that could occur over the strainer mission time. In response, the licensee provided plots of the tests showing head loss values were decreasing at test termination. This decreasing behavior indicates that extrapolation to the full mission time is not necessary. In addition, the RIG-89 testing was run for 30 days which represents the design mission time of the strainer. Since the test was run for the mission time, no extrapolation for extended operation is required.

NRC STAFF CONCLUSION

Based on the test results provided by the licensee, the NRC staff concluded that the head loss portion of the analysis has been completed adequately. Testing and analysis was conducted using NRC approved guidance. The other information provided by the licensee, either previously or in the recent submittals, provide adequate documentation that the strainer will perform its function during any required recirculation operation. 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 head loss and vortexing evaluation for the licensee acceptable. The NRC staff considers this item closed for GL 2004-02.

In its final review of information provided by the licensee, the NRC staff noted that some information regarding strainer bypass was provided and noted that the information could be non-conservative due to sample timing. Since the fiber bypass information was not relevant to the head loss and vortexing evaluation, the NRC staff determined that the evaluation was acceptable. This calculation of fiber penetration of the strainer is included in the in-vessel downstream effects area.

NRC STAFF CONCLUSION:

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

9.0 NET POSITIVE SUCTION HEAD

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through May 16, 2013. The NRC staff concluded that the licensee provided the information requested by NRC approved guidance and that the licensee responses showed that the NPSH evaluation was conducted in accordance with the guidance.

The Summer ECCS and CSS utilize two separate sumps to supply water to the A and B trains during recirculation. One train of ECCS and CSS are aligned to each sump. The supplemental response states that the maximum flow rate for a single residual heat removal (RHR) pump is attained if the other pump fails. The basis for the maximum RHR flow rate and the spray pump flow rates was not provided. In addition, the basis for the required NPSH for each pump was not provided.

The assumptions used to calculate the containment water level appeared to be conservative, but some relevant information was not provided. For example, the mass of water supplied by the refueling water storage tank (RWST) was stated to be “minimum RWST injection,” but it was not stated that this was the minimum RWST volume allowed by technical specifications. In addition, the extent of holdup in the refueling canal was not adequately described.

The NRC staff requested that the licensee validate that the RWST water level used in the minimum water level calculation was based on the Tech Spec minimum value. The licensee stated that the water inventory credited for the sump water level calculation was based on the minimum Tech Spec level. The amount credited included penalties to account for instrument uncertainty and the time required to swap from the RWST injection to sump recirculation. The NRC staff concluded that the RWST volume credited was in accordance with the approved guidance.

The NRC staff requested that the licensee provide the amount of holdup assumed in the refueling canal and the basis for the assumption that the refueling canal drain line cannot be blocked by debris. The licensee stated that the minimum flood level calculation was revised to include a water holdup for the refueling canal, account for an increase in the RB Spray pump flow and remove a simplification that resulted in an overly conservative RB spray transit holdup volume. The updated calculation resulted in no change in containment flood levels. The licensee provided information that justified that fibrous debris that might block the refueling canal drain line could not transport into the refueling canal. The licensee separately evaluated the potential for RMI to block the refueling cavity drain. The licensee concluded that it was unlikely for RMI to reach the refueling cavity, but if it did that small pieces of RMI debris could be swept to the drain. However, these pieces would not be able to block the line. The NRC staff found the response to be acceptable because the licensee demonstrated reasonable assurance that the refueling canal drain would not block and sump level would not be adversely affected.

The NRC staff requested that the licensee provide a technical basis for the pump flow rates used in the NPSH evaluation. The licensee provided the recirculation flow rates used for the analyses. The RAI response stated that the maximum RHR pump flow rates were calculated using a computer code using physical plant data. The model results were benchmarked against startup data. The licensee concluded that the RHR flow rates were calculated using conservative bounding methodologies. The response also stated that the RB spray flow had been revised to reflect appropriate vendor input. RB spray pump flow was increased from 3,000 to 3,300 gallons per minute (gpm). The maximum flow rate was calculated by plotting the pump performance curve and system resistance curves. The licensee stated that piping component losses were decreased to add conservatism to the calculation, the RB Spray Pump maximum performance curve was assumed, and other conservative inputs were used. The methodology was stated to be conservative and bounding. The licensee also stated that the increase in RB Spray pump flow rate is within the margins included in the strainer test inputs and the debris transport evaluation and provided comparisons with the original calculation inputs to confirm that the analysis remained valid. The flow rate used in the transport calculation was conservative due to higher than actual flow rates in the RHR pumps. The only changes in transport were increases in washdown transport due to the higher spray flow. (However all debris was already conservatively assumed to wash down.) The licensee described some localized recirculation transport effects that could occur to the higher spray flow and washdown. These effects were described as having no impact on the transport calculation either as shown by evaluation, existing conservatism in the calculation, or large distances from transport paths to the strainer with quiescent areas between the washdown locations and strainer flow paths. The licensee also provided updated results for NPSH calculations based on the revised RB Spray Pump flow rates and updated strainer head loss values. (Note that the head loss values decreased based on later chemical effects testing.) The NPSH margins were shown to be positive for all pumps at high and low temperatures. The NRC staff reviewed the methodology used to calculate the pump flow rates and concluded that they were acceptable because they were calculated using industry standard methodology and computer codes. The code used by the licensee is also used for accident analysis and is therefore considered to be adequate. Additionally, the licensee used conservative inputs for the calculations.

The NRC staff requested that the licensee provide a technical basis for the NPSH required values for the pumps taking suction from the containment sump. The licensee stated that the RHR pump NPSH required values were determined by using vendor certified performance curves. The procurement specifications for the pumps invoked Hydraulic Institute guidelines and that the performance curves covered a range of flows up to 4,500 gpm. The licensee also stated that the RB Spray Pump NPSH required values were determined based on Hydraulic Institute guidelines, but that the pumps were only tested at a single flow rate of 2,520 gpm. The required NPSH for the spray pumps was determined by comparing the pump tested values with vendor characteristic curves for the tested and operating flow rates and adjusting the value to account for the difference. The NRC staff noted that the actual maximum RHR pump flow rate is 4,300 gpm and the actual maximum RB Spray Pump flow rate is 3,300 gpm. The NRC staff agrees that using Hydraulic Institute guidelines are appropriate for determining the pump required NPSH required. Since the RHR pumps are operated within the tested flow range the use of the test results are appropriate. The use of the vendor characteristic curves for determination of required NPSH for the RB Spray Pumps is acceptable as it was supplemented by a pump specific test. Therefore, the NRC staff concluded that the licensee's methodology is acceptable.

The NRC staff requested that the licensee provide an evaluation of NPSH margin during hot-leg recirculation. The licensee stated that there are two potential flow alignments for hot-leg recirculation. For the preferred alignment flows were calculated to be slightly lower than those during cold-leg recirculation. Therefore, for this case cold-leg recirculation is bounding. For the alternate flow alignment, a calculation of flow rate was not performed. However, the licensee stated that in the alternate alignment that each RHR pump discharge flows through 2 six-inch injection lines as opposed to 3 six-inch injection lines for the preferred alignment. The licensee concluded that the flows in the alternate alignment would be lower due to the reduced flow area. The NRC staff agreed that the licensee's evaluation demonstrated that flows during all hot-leg recirculation alignments would be lower than during cold-leg recirculation. Therefore, the cold-leg NPSH margins are limiting.

NRC STAFF CONCLUSION:

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

10.0 COATINGS EVALUATION

The objective of the coatings evaluation section is to determine the amount of plant-specific ZOI generated debris (qualified coatings), the amount unqualified coating debris and the debris characteristics for coatings for use in determining the eventual contribution of coatings to overall head loss at the sump screen.

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008. The guidance documents used for the review include the "Revised Guidance Regarding Coatings Zone of Influence For Review of Final Licensee Responses to Generic Letter 2004-02" (ADAMS Accession No. ML100960495) and RG 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident."

The licensee used a ZOI methodology based, in part, on WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings" (ADAMS Accession No. ML061990594. The Service Level I Coatings ZOI was modeled as 4 pipe diameters (4D) and is applicable to qualified epoxy-epoxy and zinc-epoxy coating systems. The NRC staff accepted the confirmatory testing and analysis by Westinghouse that shows that a ZOI of 4D for epoxy coating systems is acceptable (ADAMS Accession No. ML100960495). The licensee stated that there is no qualified untopcoated inorganic zinc coating system in containment. All unqualified coating is assumed to fail as particulate.

The licensee performed head loss testing, which included tests to evaluate thin bed formation and to identify cases where thin bed formation does not occur. The Summer strainer design is such that thin bed formation is unlikely to occur. For the test case in which thin bed formation was evaluated, the licensee stated that all unqualified coatings were modeled as fine particulate. Additional fiber was added to this test to characterize head loss with higher levels of fiber loading to evaluate when the onset of thin bed formation would occur. The licensee stated that although head loss increased above the clean strainer head loss, a thin bed did not form and the head loss was within the allowable NPSH margin. The NRC staff reviewed this approach and found it acceptable based on the NRC SE of NEI 04-07.

In the head loss test case where thin bed formation was not being evaluated, unqualified epoxy and degraded qualified epoxy coatings were treated as chips. The licensee stated that the coating chip additions were approximately 4.5 times greater than the calculated debris loading. The technical justification for treating the epoxy coating as chips is based on a Keeler and Long Report, "TXU Paint Chip Characterization" (ADAMS Accession No. ML081770357). The licensee calculated the paint chip size distribution based on the report and subsequently performed a transport analysis. However, the test used a different chip size distribution. In the report, slightly less than 50 percent of the chips were larger than 0.25 inch (see Table 1) and in the test chip distribution used by Summer, almost all the chips were larger than 0.25 inch (see Table 2). The NRC staff noted that in the Summer test chip distribution, almost all of the chips were larger than the strainer openings.

Table 1 – Keeler and Long Report Paint Chip Size Distribution by Mass

Size Range of Coating	No. of Pieces	Mass (gram)	Percentage of Total Mass (%)
1 – 2"	17	3.4657	32.0
0.5 – 1"	25	0.9784	9.04
0.25 – 0.5"	43	0.4774	4.41
0.125 – 0.25"	103	0.5434	5.02
< 0.125"	NA	1.5901 + 3.766	49.5
Total		10.821	100

Table 2 –Summer Epoxy Paint Chip Distribution for Head Loss Test without Thin Bed

Chip Size	Total Chip Surface Area (ft^2)	Surface Area per Addition (ft^2)	Debris Loading Calculation (ft^2)	Percentage of Total Mass (%)
1 – 2”	893	297.7	582	26
0.5 – 1”	2027	675.7	165	59
0.25 - 0.5”	447	149	0	13
< 0.25”	7	2.3	0	2
Total	3436	1145.3	747	100

The NRC staff reviewed the differences between the Keeler and Long data and the Summer test distribution and found them to be acceptable since the licensee performed tests that indicated both distributions would have the same effect on the strainer in Head Loss testing. In addition, for those plants that claim that formation of a fibrous thin bed is unlikely, the NRC staff finds the use of larger sized chip coating debris type to be conservative with regards to sump blockage testing. The NRC staff has reviewed the report and the licensee’s approach and finds that treating epoxy coating as chips is acceptable based on the NRC SE of NEI 04-07.

The licensee’s coating assessment program is acceptable to the NRC staff since it is conducted every two years or during each refueling outage by qualified personnel, and if degraded coatings are identified, they are documented and additional tests and remediation may be performed.

NRC STAFF CONCLUSION:

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

11.0 DEBRIS SOURCE TERM

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through May 16, 2013.

The NRC staff found the licensee’s foreign materials exclusion (FME) program, Quality Control (QC) containment closeout inspections, and Surveillance Test Procedures to be acceptable in ensuring that potential quantities of post-accident debris are maintained within the bounds of the analyses and design bases that support ECCS and CSS recirculation functions.

The licensee’s FME program, “Station Administrative Procedure-363 (SAP-363),” is described to all personnel as part of Site Orientation Training and includes instruction on responsibilities, foreign material types, and operating experience. The licensee’s QC organization maintains its own FME program of the RB following outages using a two-part (preliminary and final) containment closeout inspection per Quality Services Procedure QSP-522. In conjunction with QSP-522, the licensee uses Surveillance Test Procedure STP-109.001 to ensure all remaining debris is cleared from the RB; STP-109.001 is the final procedure implemented before closing out the RB in preparation power operation. The licensee uses procedure OAP-108.1 to control RB entries at power; the RB is treated as an FME area at power. Due to as low as reasonably achievable (ALARA) considerations and the use of FME controls, QC does not perform its containment closeout inspections at power.

The licensee updated the Cumulative Effects Program of the Engineering Change Process to track important design inputs that support the GSI-191 issue resolution. A summary of those changes are as follows:

- The existing program that tracks aluminum inside the RB for hydrogen control was revised to include the chemical effects aspects of GSI-191. The same design margin used for hydrogen control was used for chemical effects.

- A new program was added to track unqualified coatings inside the RB. The program is referenced to the unqualified coatings calculation which lists the unqualified coatings and design margins.

- A new program was added to track insulation inside the RB. This program is referenced to the debris generation calculation which lists the insulation and reference drawings.

- A new program was added to track the addition of structures or components inside the loop compartments that may fall within the qualified coating ZOI.

The licensee put control measures in place to limit non-metallic insulation from being installed in the RB using Engineering Change Requests or Equal To or Better Than modification packages, and it maintains the status of existing insulation in the RB using the Design Control System database.

NRC STAFF CONCLUSION:

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

12.0 SCREEN MODIFICATION PACKAGE

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through May 16, 2013.

The licensee stated that the Summer sump configuration consists of two sumps, A and B, for which the surface area is distributed between RHR and spray systems as:

Sump A: A RHR – 1,405 ft^2, A RB Spray – 1,534 ft^2, Total Sump A: 2,939 ft^2

Sump B: B RHR – 1,251 ft^2, B RB Spray – 1,129 ft^2, Total Sump B: 2,380 ft^2

The RHR and RB Spray strainer modules are interconnected by a cross-duct to allow water to flow from one module to the other assuming one of the strainer modules becomes heavily blocked by debris.

In the event of a LOCA, water from the spray nozzles and water spilled through the break in the RCS is collected in the recirculation sumps. Each of two sumps has a suction line to an RHR pump and a RB Spray pump. Each of the recirculation sumps is surrounded by a 6-inch-high curb. The sump pits containing the strainers are recessed below the basement floor with the top of the strainers just below the floor elevation. The strainers discharge downward into sumps from which the pumps take suction.

A removable stainless steel grating walkway is provided over the sump to allow personnel access in the area and support maintenance in the area. The grating is designed to remain in place during plant operation. A large opening is provided through the grating to ensure adequate flow for the postulated worst case, assuming full blockage of the grating by debris transported to the sump following the postulated pipe break.

Each vertically oriented strainer fin consists of 18-gauge stainless steel sheets, perforated with 1/16" diameter holes. The surfaces of the fins are corrugated to increase their surface area. As the water level rises in the strainer during filling, air can escape through the fins and through the vent holes provided at the top of the strainer header box. This design ensures that there is no risk of air ingestion due to trapped air pockets during filling.

The header boxes, strainer fins, and cross ducts are designed, fabricated, and installed in accordance with American Society of Mechanical Engineers (ASME) Code and Seismic Category 1 requirements. A removable plate is provided for personnel access into the pit below the strainers.

NRC STAFF CONCLUSION:

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

13.0 SUMP STRUCTURAL ANALYSIS

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

NRC STAFF REVIEW:

The NRC staff's review is based on the licensee's February 29, 2008 submittal, as well as proprietary information submitted on September 9, 2008 (ADAMS Accession No. ML082590341). The licensee provided additional information in its November 29, 2009 RAI response. The guidance documents used for the review include the November 2007 Revised Content Guide and RG 1.82.

The licensee stated that the modified recirculation sump strainer assembly was structurally analyzed using a combination of manual calculations and finite element analysis. The strainers were designed for live, thermal, and seismic loads. Detailed information regarding the design inputs, design codes, loads, acceptance criteria, and analysis method was provided in the licensee's September 9, 2008 proprietary submittal. The proprietary submittal provided details on the computer models developed for the strainer and the subsequent finite element analyses which were performed with the model, including a detailed description of the loads and bounding load combinations applied to the strainer model to demonstrate structural integrity. The results of the analyses show that adequate design margin exists based on the actual and code allowable stresses the strainer experiences under the loading combinations.

The licensee indicated that the strainers are located outside the bio-shield wall in areas where pipe whip or missile loads would not be a concern. The NRC staff verified that the strainers are located in an area that precludes adverse effects associated with potential pipe whip or jet impingement.

The license's submittal did not credit a backflushing strategy. Therefore, consideration of reverse flow loading was not required in the structural evaluation.

RAI REVIEW:

The licensee's proprietary report noted that the 2004 ASME Code was used in the structural evaluation; however, when the report was originally submitted, the 2004 edition of the ASME Code was not explicitly endorsed by NRC regulations. To address this, the NRC staff issued an RAI, which the licensee responded to in a letter dated November 29, 2009. The response stated that for the portions of the ASME Code used in the analysis, there are no discrepancies between the NRC endorsed editions and the edition used for the analysis. Based on this comparison, the NRC staff found the use of the 2004 ASME Code acceptable.

NRC STAFF CONCLUSION:

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

14.0 UPSTREAM EFFECTS

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

NRC STAFF REVIEW:

The NRC staff review is based upon documentation provided by the licensee through February 29, 2008.

The NRC staff found that there are no curbs or debris interceptors in the Summer design which will hold up or choke water flow return to the sump pool and that the licensee adequately evaluated potential water holdup volumes.

Spray Wash Down

The licensee stated that the spray flow will return to the RB sump pool by one of four paths, which are all modeled in the Computational Fluid Dynamics calculation.

1. Spray flow landing on the concrete operating deck at the 463 ft. elevation will return via the equipment hatch or one of the two stair wells. There are no curbs at these locations. There are curbs or toe-kick plates at all other locations to direct the spray flow. A 2-inch water level is assumed on the operating deck.

2. Spray flow may enter the steam generator cubicles directly. There are no solid floors within the cubicles (grating only), so the flow returns directly to the sump pool.

3. Spray flow may drop between the operating deck and the RB wall. The operating deck is not cylindrical, and openings are provided between the floor and the RB wall. This spray flow returns directly to the sump pool.

4. Spray flow directly entering the refueling cavity returns to the sump pool via an 8” line into the normal RB sump. The normal RB sump is located on the same elevation as the sump pool. A 2-inch continuous curb around the refueling cavity prevents water from the 463 ft. operating deck from entering the refueling cavity.

The licensee also stated that two other small wash down paths are also available, but not specifically modeled. The pressurizer cubicle has three small openings. Some small amount of spray flow will enter the cubicle and empties on to the mezzanine level at the 436 ft. elevation. This is covered by the 2-inch water level assumption for the 436 ft. elevation. The spray flow may also enter the reactor vessel cavity around the vessel head seal. This seal is used during refueling operation. During power operation, a small gap is available for spray flow to enter the reactor vessel cavity. This is covered by the assumption that the cavity fills to the RCS cold-leg primary shield wall penetrations.

Break Location and Choke Points

The licensee identified three possible break areas which have different characteristic break flow return paths.

1. A break in any one of the steam generator cubicles will spill directly into the sump pool. The same holds for the pressurizer surge line. These break locations are all within the bio-shield wall. There are three openings in the bio-shield wall which allow flow out to the sump strainers. Flow is not choked at the bio-shield exits.

2. A break at the reactor vessel safe end is inside the primary shield wall. A baffle assembly directs the initial LOCA jet out the primary shield wall penetration and up into the RB above the reactor vessel. Spill flow during recirculation is directed out of the primary shield wall penetration, directly into the sump pool. Some flow may drain between the baffle assembly and reactor vessel into the vessel cavity. This potential holdup is accounted for by the

assumption that the cavity fills to the RCS cold-leg primary shield wall penetrations. (See Reactor Vessel Cavity Section below.)

3. A break in one of the pressurizer safety valve or power operated relief valve lines would result in spill flow inside the pressurize cubicle. The pressurizer cubicle door does not present a hold up concern. Flow would exit the pressurizer door on to the mezzanine level at the 436 ft. elevation. Two 8-foot lengths of toe kick plate have been removed from the mezzanine level (in the vicinity of the equipment hatch) to provide a larger flow path to the sump pool. Prior to the modification, the flow return to the sump pool via one of two stairwells. The stairwell adjacent to the A train sump was provided with a gate to direct flow away from the sump.

Reactor Vessel Cavity

The licensee stated that hold up in the reactor vessel cavity has been taken into consideration. Two stainless steel dampers isolate air flow out of the cavity at the sump pool elevation and are assumed to adequately restrict flow out of the cavity resulting in cavity fill to the primary shield penetrations for the main reactor coolant loop piping. This slightly reduces the sump pool level.

Refueling Cavity

The licensee stated that the refueling cavity is drained by an 8-inch diameter pipe. The drain opening is located on the floor level in the cavity at an elevation of 423 feet, 5.25 inches. The pipe discharges into the normal RB sump (at a location away from the recirculation sump strainers). There are no valves in the line. During refueling operation, a blind flange is installed to block the drain flow path. The licensee stated that based on the assessment summarized below, a debris interceptor for the refueling cavity drain is not required.

The licensee stated that a continuous two-inch curb is provided around the refueling cavity at the 463 foot operating deck elevation. During post-LOCA conditions, this curb prevents water collected on the operating deck (from the spray flow) from entering the refueling cavity, thereby, limiting the amount of water that must drain from the refueling cavity through the 8 inch pipe. The curb also prevents wash down of any debris from the operating deck into the refueling cavity. The Summer containment is highly compartmentalized. The shield wall around the steam generators extends up to an elevation of 475 feet, 5 inches on the side facing the refueling cavity.

The licensee also stated that the limiting design break at the steam generator outlet is at an elevation of 431 feet. Debris large enough to block the 8 inch diameter drain is not expected to be carried up and over this elevation difference.

The licensee further stated that If it were postulated that large debris were to dislodge from the top of the steam generator and fall laterally into the refueling cavity, it would then have to transport to the 8 inch drain line. The insulation on the steam generators is reflective metal cassettes. The failure mechanism for a cassette located near the top of the steam generator is for the cassette buckle to fail and the cassette to break open as it impacts the floor. The refueling cavity drain line is located near the containment wall in the fuel transfer cannel, well away from the steam generators. Testing has shown that water readily flows through a pile of crumpled RMI debris.

NRC STAFF CONCLUSION:

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

15.0 DOWNSTREAM EFFECTS - COMPONENTS AND SYSTEMS

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

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through May 16, 2013.

The licensee evaluated downstream effects on components and systems based on guidance provided in Revision 1 of WCAP-16406-P, "Evaluation of the Downstream Sump Debris Effects in Support of GSI-191," the NRC SE for WCAP-16406-P, NEI 04-07, and the NRC SE for NEI 04-07. WCAP-16571, "Test of Pump and Valve Surfaces to Assess the Wear from Paint Chip Debris Laden Water," Revision 0 was used to supplement erosion data. The licensee stated that the calculations confirm that with the replacement of the HHSI throttle valves, that safety injection (SI) and RB spray operation during small-break, medium-break, and LBLOCAs would be adequate to meet the requirements of the Summer accident analyses.

The licensee stated that the evaluation of downstream effects of ingested debris on auxiliary equipment in Summer included valves, pumps, heat exchangers, orifices, spray nozzles, and instrumentation tubing. The effects of debris ingested through the containment sump strainers during the recirculation mode of the SI and RB spray include erosive wear, abrasion and potential blockage of equipment and flow paths. The calculations also document an assessment of changes in system or equipment operation caused by wear, including an evaluation of pump hydraulic performance due to internal wear.

The licensee stated that the downstream effects evaluation prompted the replacement of the high head SI throttle valves. The new valves are Y-pattern Edward Pressure-Combo globe valves which feature a flow nozzle at the valve outlet. The flow nozzle provides a large pressure drop, thereby, allowing the valve to be opened further. The new minimum valve opening is approximately 3/32" compared to a sump strainer opening of 1/16" diameter. The licensee did not identify the need for any other physical or operational plant changes.

The licensee stated that with the debris loading expected during post-LOCA conditions, the pump seals may not be limited to a 50 gpm leak rate and that the carbon/graphite disaster bushings in the pump seals may not limit pump seal leakage to 50 gpm if the primary seal fails. The licensee stated that neither the pump vendor nor the NSSS vendor, have replacement seal packages without the carbon/graphite bushing nor have plans to develop one. To eliminate the need for replacing the seal, the licensee prepared an Alternate Source Term dose analysis and submitted an LAR with the information dated February 17, 2009 (ADAMS Accession No. ML090720887). The NRC staff approved the LAR October 4, 2010 (ADAMS Accession No. ML102160020). The LAR implemented an AST application methodology for analyzing the radiological consequences for six -DBAs. The AST amendment eliminated the need to assume a passive failure of a pump seal at 24 hours after an accident, as required by the previous licensing basis dose analysis. This eliminated the concern regarding the use of carbon/graphite disaster bushings in pump seals. With no primary seal failure assumption in the AST licensing basis dose analysis, there is no design requirement to limit the pump seal leakage to 50 gpm, and the carbon/graphite disaster bushings are no longer required to be replaced.

RAI REVIEW:

There were RAIs in this area related to the wear evaluation and replacement pump seal assembly calculations from February 3, 2009. The RAI responses from November 29, 2009 were evaluated by the NRC staff.

In the RAI responses the licensee confirmed that the expected seal leakage does not diminish the pump(s) capacity below that required to accomplish the pumps design function. This showed that reduced pump performance would not occur with a failed seal.

The licensee also explained that the expected pump seal leakage is not accounted for in the compartment flooding evaluation because a pipe rupture considered for flooding is not assumed to occur simultaneously with a LOCA and post-accident long term recirculation. This means that the pipe rupture leakage rate is not added to the assumed seal leakage rate in any design basis analysis. Considering this, the flow rate after a pipe rupture of a feedwater line or in a charging pump compartment is at least one order of magnitude larger than the pump seal leakage rate. Therefore, the pump seal leakage rate for any charging pump, RHR pump, or reactor building spray pump is bounded by a feedwater line break.

The licensee identified that wear of the pump seals cold result in leakage greater than 50 gpm. In order to address the potential dose issues from the leakage the licensee submitted a LAR for Alternate Source Term to the NRC. The LAR was approved (ADAMS Accession No. ML102160020). This addresses the issue of potential leakage from the pump seals.

The licensee described how the wear evaluation was performed for Summer using data extracted from WCAP-16571-P. The NRC staff reviewed the application of the topical report and found it to be acceptable (ADAMS Accession No. ML100920035).

The NRC staff concludes that the licensee has sufficiently addressed all RAIs relating to downstream effects components and systems.

NRC STAFF CONCLUSION:

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

16.0 DOWNSTREAM EFFECTS - FUEL AND VESSEL

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

NRC STAFF REVIEW:

The final NRC staff review is based on information submitted by the licensee through June 17, 2021.

The licensee stated that it applied the clean plant criteria to determine the amount of fibrous debris penetrating the sump strainers for use in the downstream in-vessel debris effect analysis for Summer. The licensee used a fiber penetration (bypass) fraction of 45 percent and a debris transport fraction of 75 percent.

The licensee determined the in-vessel debris loading by determining the mass of fiber that penetrates the strainer. Sources of fiber at Summer are Temp-Mat and latent fiber. The licensee determined the fiber load that could bypass the strainers and transport to the core inlet by evaluating the latent debris sources and the transportable debris originating from Temp-Mat blankets (including erosion).

The licensee determined the total quantity of fibrous insulation debris generated in the bounding break, including fiber fines, eroded small and large pieces of fiber, and latent fiber. The licensee determined that the RCS A Loop 31” crossover line double-ended guillotine break creates the largest amount of fibrous debris, 15.49 cubic feet (ft^3). The total fiber load for evaluation of in-vessel effects consists of eroded Temp-Mat pieces (4.96 ft^3 from exposed blankets and 4.18 ft^3 from small pieces) and fines (1.08 ft^3). The licensee conservatively assumed that fines completely pass through the sump strainers, so the fiber load of 1.08 ft^3 is added to the fiber created through erosion to establish the total fiber load used for in-vessel debris effects. The licensee calculated the fiber strainer bypass using the methodology in WCAP-17788-P, Revision 1 “Comprehensive Analysis and Test Program for GSI-191 Closure” (ADAMS Package Accession No. ML20010F181), which only requires consideration of fibrous and chemical product debris and bounds all particulate loads. The licensee converted the volume of Temp-Mat fine fiber to pound mass (lbm) (12.74 lbm).

The licensee determined the reactor building latent debris as 105 lbm (which includes margin). Per NEI 04-07, the size distribution of latent debris is 15 percent fibrous and 85 percent particulate. Therefore, the latent fiber load considered is 16 lbm.

The licensee determined the quantity of erosion products created during a LOCA at 8 hours into the event from exposed insulation blankets and small pieces of Temp-Mat.

The licensee calculated the percentage of eroded fiber generated from the small pieces and exposed Temp-Mat blankets using the following equation:

$$f_{eroded} = 1 - (1 - rate)^{\text{number of hours}}$$

The licensee used an erosion rate of 0.3 percent from NEI 04-07 and the maximum Summer Hot Leg Switch Over (HLSO) time of 8 hours and calculated the percentage of eroded fines generated at HLSO as 2.375 percent. The licensee then applied the erosion percentage to the amount of exposed blankets and small pieces of Temp-Mat insulation (resulting in 0.118 ft^3 and 0.0993 ft^3, respectively) and determined the total amount of eroded fines as 0.218 ft^3 or 2.57 lbm.

The licensee determined the total fiber load for the strainer calculation. The license determined the total fiber transported to the strainers as: 2.57 lbm + 12.74 lbm + 16 lbm = 31.31 lbm. The licensee then calculated the strainer bypass using the NEI clean plant 45 percent bypass factor to determine the amount of fibrous debris calculated to arrive at the reactor vessel. The calculated in-vessel fiber load is 40.7 grams per fuel assembly (g/FA).

The licensee stated that Summer is a Westinghouse 3-loop upflow barrel/baffle configuration plant design. Summer's core consists of 157 VANTAGE+ 17 x 17 optimized fuel assemblies. This fuel design is in Table RAI-1.1-1 of WCAP-17788, and has the same pitch as that evaluated, therefore no scaling is needed to adjust the core inlet debris load. The proprietary total in-vessel fibrous debris limit contained in Section 6.5 of WCAP-17788 applies to Summer. The licensee assumed that all fibrous debris calculated to penetrate the strainer reaches the reactor vessel. The licensee stated that the maximum amount of fiber to potentially reach the reactor vessel is 40.7 g/FA, which is less than the proprietary in-vessel fibrous debris limit in WCAP-17788.

The licensee stated that the sump switchover (SSO) time for maximum ECCS flow (using the design bases reactor building spray pump flow of 3,000 gpm/pump for LOCA pressure and temperature) is 1,460 seconds, or 24.4 minutes. The SSO time with a maximum reactor building spray pump flow of 3,381 gpm resulting from overfill of the RWST when containment backpressure is 0 psi gauge, is 1,382 seconds, or 23.0 minutes. Both SSO times are greater than the 20 minutes assumed in the TR analysis and listed in Table 6-1 of WCAP-17788.

The licensee stated that based on Table 4.4-1 of PWROG-16073-P, Rev. 0, "TSTF-567 Implementation Guidance, Evaluation of In-Vessel Debris Effects, Submittal Template for Final Response to Generic Letter 2004-02 and FSAR [Final Safety Analysis Report] Changes," Test Group 11 is representative of Summer and therefore, the predicted chemical precipitation timing (t_{chem}) is 24 hours. The NRC staff reviewed the WCAP 17788-P Volume 5 test data and verified that the information supports the licensee's statement that chemical precipitates are not expected prior to 24 hours.

The licensee stated that switchover to hot-leg recirculation occurs no later than 8 hours after event initiation (post-LOCA) to mitigate the potential for boric acid precipitation HLSO occurs prior to 24 hours following event initiation. The licensee stated that based on WCAP-17788, Volume 1, Table 6-1, t_{block} for Summer is 143 minutes. Based on Table 4.4-1 of PWROG-16073, the earliest time of chemical precipitation for Summer is 24 hours, which is greater than the applicable t_{block} of 143 minutes.

The licensee stated that the applicable analyzed thermal power in WCAP-17788, Volume 4, Table 6-1 is 3,658 megawatts thermal (MWt). Summer has a rated thermal power of 2,900 MWt, which is less than the analyzed power and is therefore bounded by the WCAP-17788 alternate flow path (AFP) analysis.

The licensee stated that the applicable proprietary analyzed AFP resistance for a 3-loop Westinghouse upflow barrel/baffle configuration design is in Table 6-1 of WCAP-17788, Volume 4. The proprietary Summer specific AFP resistance is in Table RAI-4.2-24 and is less than the analyzed value and therefore bounded by the resistance applied to the AFP analysis.

The licensee stated that the AFP analysis for Westinghouse upflow plants analyzed a range of ECCS recirculation flow rates as shown in Table 6-1 of WCAP-17788, Volume 4. The minimum Summer ECCS recirculation flow rate analyzed is 21.9 gpm/FA, and the maximum ECCS recirculation flow rate is 37.7 gpm/FA. The Summer ECCS recirculation flow rate corresponding to the most limiting fiber injection hot-leg break scenario is 22.7 gpm/FA. Therefore, all of these flow rates are within the range of ECCS recirculation flow rates considered in the AFP analysis.

The licensee stated that it used the clean plant criteria to determine the amount of fiber that could transport to and penetrate the strainer. However, it did not implement the criteria correctly. The clean plant criteria require that 75 percent of all generated fiber, including small and large pieces, be assumed to transport and contribute to the amount penetrating the strainer. The licensee's evaluation assumed that the uneroded portions of small and large pieces of fiber did not transport to the strainer. However, the licensee assumed that 100 percent of the fine fiber from generated debris, eroded debris, and latent debris reached the strainer. The NRC staff considers 100 percent transport of fines to the strainer to be conservative for penetration calculations. Therefore, the NRC staff concluded that the amount of fiber assumed to transport to the strainer was acceptable considering the other assumptions used in the analysis and the discussion below.

The licensee did not adequately justify its evaluation of erosion of the large and small pieces of fiber. The licensee used erosion metrics and an equation that were developed before an adequate empirical database of erosion metrics had been developed. The equation used by the licensee used a 90 percent erosion fraction and assumed that erosion is constant over time. The NRC staff noted that neither of these assumptions has been validated so the equation's validity is doubtful. The use of the equation resulted in an erosion fraction of 2.375 percent over 8 hours. More recent proprietary testing has provided a knowledge base of erosion behavior. Based on the testing, the NRC has allowed licensees to use an erosion fraction of 10 percent over 30 days if the test results are demonstrated to be applicable to the plant. For its in-vessel analysis, Summer has to account for erosion for only 8 hours. To determine whether the licensee's estimate was reasonable, the NRC staff reviewed the data from the erosion testing. The data from the testing for low-density fiberglass indicate the erosion rate was likely significantly lower than 10 percent. Also, the erosion rate for Temp-Mat is expected to be somewhat lower than that for low-density fiberglass because Temp-Mat is a higher density material that is more robust. Because the tested erosion value was lower than 10 percent, Temp-Mat is more robust than low-density fiberglass, and the licensee only had to account for erosion for 8 hours versus the test duration of 30 days, the NRC staff concluded that the licensee's erosion fraction of 2.375 percent for 8 hours is reasonable. The NRC staff emphasizes that 10 percent is the approved erosion fraction for licensees that demonstrate that the proprietary testing is applicable to their plant conditions.

To gain a better understanding of the potential maximum amount of debris that could reach the core inlet, the NRC staff calculated the amount of fiber that would reach the core using the licensee's assumptions, except the NRC staff used a 10 percent erosion rate. The NRC staff calculation resulted in a fiber load of 51.3 g/FA. This value is only slightly higher than the core inlet debris limit calculated for the plant-specific conditions at Summer. The NRC staff concluded that the erosion value would be less than 10 percent and that the amount of debris reaching the core inlet would not exceed the approved criterion. An additional mitigating factor is that even if the erosion value did reach 10 percent, the Summer total in-vessel fibrous debris amount would be much less than the limit. (There are two acceptable fiber limits, a core inlet limit and a total in-vessel limit.) The NRC staff has determined that plants that meet all of the acceptance criteria in the NRC staff guidance and calculate a total in-vessel fibrous debris limit less than the total in-vessel limit, but greater than the core inlet limit, will maintain adequate core cooling due to the core inlet flow patterns leading to non-uniform debris collection at the core inlet.

The clean plant criteria require the assumption that 45 percent of the fiber arriving at the strainer penetrates. The licensee retained this assumption. The NRC staff finds that this assumption is acceptable because testing has demonstrated that 45 percent is the highest penetration fraction obtained with very little fiber on the strainer and hydraulic conditions similar to those at a PWR strainer. As the fiber load on the strainer increases, the penetration fraction decreases quickly. Therefore, the NRC staff finds the use of a 45 percent penetration fraction acceptable.

The licensee's submittal also demonstrated that there is margin in the in-vessel evaluation because the rated thermal power at Summer is significantly lower than the WCAP-17788-P model plant. Summer also has more time before SSO than the evaluated model. These two factors result in reduced decay heat at the time of SSO. This reduces the amount of flow needed to maintain core cooling. Additional margin exists because the Summer AFP resistance is lower than the model evaluated resistance. Finally, the licensee did not assume fiber depletion due to fiber that would enter the RB spray system and recirculate to the pool resulting in an additional opportunity to deposit on the strainer. This conservatively maximizes the amount of fiber predicted to reach the core inlet.

In summary, the licensee's calculation for the amount of fiber arriving at the strainer misapplied the clean plant criteria and used unsubstantiated erosion metrics. However, based on the discussion above, the amount of fiber reaching the reactor vessel at Summer is reasonably assured to be within the acceptance criteria for the plant design. Also, there are other conservatisms and margins in the Summer evaluation as described above. Chemical effects testing documented in WCAP-17788-P showed that precipitates would not form before 24 hours, long after the time for HLSO. The NRC staff finds that the information provided by the licensee demonstrates that the plant meets the metrics provided in NRC staff guidance for the evaluation of in-vessel effects. Therefore, the analysis is acceptable.

NRC STAFF CONCLUSION:

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

17.0 CHEMICAL EFFECTS:

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling. Chemical effects related to the reactor vessel were discussed in Section 16.

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee (ADAMS Accession Nos. ML080640545 and ML093000573), as well as the updated plant specific path and schedule for resolution of GL 2004-02 supplement submitted (ADAMS Accession

No. ML103610171). The reference documents used for this review include "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant Specific Chemical Effects Evaluations," dated March 2008 (ADAMS Accession No. ML080380214).

Summer has two Reactor Building recirculation sumps (A and B, one per strainer) that are located approximately 45 degrees apart in the annular region between the secondary shield (bio-shield) wall and the reactor building wall. The licensee installed two AECL fin strainers at Summer. The total strainer area for sump A is 2,939 ft^2 and 2,380 ft^2 for sump B. The licensee's plant-specific debris generation and transport analyses determined that the debris sources include diamond mirror RMI, TempMat, Marinite XL, Kaowool and Kaowool M-Board, and miscellaneous debris (i.e., placards, paper, tape and tags). Summer uses sodium hydroxide (NaOH) to control post-LOCA pool pH.

RAI REVIEW:

There were some outstanding RAIs regarding the chemical effects area. Initially, the licensee stated in its February 29, 2008 supplemental response letter to NRC that a chemical effects evaluation at Summer was not required since aluminum hydroxide $(AlOH)_x$ type precipitates were not expected in the Summer post-LOCA sump water. The licensee based this assertion on three cases where they varied the amount of submerged aluminum (either all unknown aluminum was assumed to be submerged or 50 percent of unknown aluminum was assumed submerged) with pH (including high pH at high temperature and low pH at low temperature) with a maximum Equipment Qualification (EQ) sump temperature profile. The licensee used a solubility argument to conclude that the aluminum in solution for the representative ECCS mission time (42 days) at Summer would remain in solution and not precipitate. The NRC staff concluded that the licensee did not provide sufficient information to demonstrate that aluminum hydroxide (e.g., AlOH) would not precipitate. Therefore, NRC staff requested additional information (RAIs 24-26) in a letter dated February 3, 2009 to help NRC staff evaluate the licensee's conclusions and technical basis used to demonstrate that no precipitation would occur. The NRC staff also requested the technical basis for why other precipitates (other than aluminum hydroxide) could not form in the post-LOCA environment in Summer sump water.

The licensee considered the NRC staff RAIs and responded with letter dated November 29, 2009, wherein the licensee committed (Commitment #3) to perform plant specific chemical effects head loss testing with results to the NRC by December 31, 2010. On December 17, 2010, the licensee submitted a response letter (ADAMS Accession No. ML103610171) to address the commitment related to the chemical effects evaluation.

The licensee used the AECL Chalk River facility to perform the chemical effects head loss testing and evaluation. The chemical effects testing protocol developed by AECL that was used for the Summer test program was different than the approaches used by other vendors based on the WCAP-16530-NP-A methodology. The WCAP methodology involves determining the chemical precipitate load, preparing the calculated amount of precipitates, and adding the pre-mixed precipitates to the test loop after a debris bed is formed on the test strainer.

For the chemical effects area, the primary concern for Summer is the corrosion of aluminum and the formation of aluminum hydroxide or aluminum oxy-hydroxide precipitate which could add to debris loading on the strainer. The chemical effects tests were run in the AECL Rig 89 test loop, a multi-loop test facility at AECL Chalk River laboratories designed specifically for chemical effects testing. NRC staff traveled to the Chalk River facility, had discussions with AECL technical staff and observed the chemical effects testing (ADAMS Accession

No. ML081400643) for another licensee. The Rig 89 test loop is the same test loop used by another licensee whose chemical effects evaluation was previously reviewed by NRC staff (ADAMS Accession No. ML090410618).

The AECL Rig 89 test loop consisted of a simulated post-LOCA pool environment containing representative amounts of boron (added as boric acid) and scaled amounts of plant specific debris. The tests were longer-term tests that included the modeling of chemical precipitation and the measurement of the head loss impact of the precipitates that accumulated in the debris bed. The test loop flow rate and strainer fin area were scaled to the installed strainer as were test debris, including aluminum added as sodium aluminate. Once the debris bed was established, sodium aluminate solution was added to the test loop in a series of 17 additions. The test was divided into three parts; Part A was conducted at 60 degrees Celsius (°C), Part B at 40 °C and Part C at 20 °C. Part C of the test was stopped prior to the last addition. The test loop pH was 7.5 which is the projected lower limit of a post-LOCA sump pool pH. Therefore, the test loop pH is conservative to the projected post-LOCA pool pH with respect to aluminum solubility. Following the final sodium aluminate addition to the test loop, the total aluminum added, on an aluminum mass per strainer area (86 g/m^2), exceeded the design basis load (73.5 g/m^2). This resulted in a conservative aluminum quantity in the test loop relative to that projected for the Summer plant post-LOCA sump pool.

The total head loss measured in the Rig 89 test loop represented the plant-specific, integrated head loss across the sump strainer for plant debris and chemical effects. The licensee calculated the aluminum release in the sump using the plant's aluminum inventory and the corresponding aluminum release contributions developed by AECL. The aluminum inventory included a surface area margin of 100 ft^2 for future operation. The design calculation for sump pool aluminum used a long-term sump pH of 8.5 and a maximum short-term spray pH of 10.5. The temperature profile for the aluminum corrosion rates was based on the maximum temperature profile for the EQ program. This resulted in a conservative calculation of aluminum release since the maximum pH value was used in the calculation. During testing, after a stable baseline (from fibrous and particulate debris) head loss was established across the test strainer section, sodium aluminate was added in 17 batches.

After evaluating the licensee's response letter from December 17, 2010, NRC staff concludes that the licensee chemical effects test results have provided sufficient information to address the commitment made to resolve chemical effects RAIs 24 to 26 from November 2009. NRC staff had previously visited the AECL test facility, observed bed formation in the Rig 89 test loop, and determined that it is adequate for performing head loss testing. The licensee performed long term chemical effects testing with a conservative amount of aluminum to demonstrate that aluminum precipitation was addressed for Summer with resulting acceptable head loss results.

NRC STAFF CONCLUSION:

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

18.0 LICENSING BASIS

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

The licensee committed to change the FSAR 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 FSAR 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

NRC STAFF CONCLUSION:

For this review area the licensee has provided information, such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Based on the licensee's commitment, the NRC staff has confidence that the licensee will affect the appropriate changes to the Summer FSAR, 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 staff considers this item closed for GL 2004-02.

19.0 CONCLUSION

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

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

Therefore, the NRC staff finds the licensee's responses to GL 2004-02 are adequate and considers GL 2004-02 closed for the Virgil C. Summer Nuclear Station, Unit 1.

SUBJECT: VIRGIL C. SUMMER NUCLEAR STATION, UNIT 1 – CLOSEOUT OF GENERIC LETTER 2004-02, “POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS” (EPID L-2017-LRC-0000) DATED SEPTEMBER 24, 2021

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RidsRgn2MailCenter Resource
SSmith, NRR
ARussell, NRR
LRegner, NRR
MYoder, NRR
PKlein, NRR
BLehman, NRR

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OFFICE	NRR/DORL/LPL2-1/PM	NRR/DORL/LPL2-1/LA	NRR/DSS/STSB/BC(A)
NAME	VThomas	KGoldstein	NJordan
DATE	07/29/2021	9/22/2021	07/28/2021
OFFICE	NRR/DNRL/NCSG/BC	NRR/DORL/LPL2-1/BC	NRR/DORL/LPL2-1/PM
NAME	SBloom	MMarkley (GEMiller for)	GEMiller
DATE	9/17/2021	9/24/2021	9/24/2021

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