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

June 24, 2022

Mr. Joel P. Gebbie
Senior Vice President and Chief
Nuclear Officer
Indiana Michigan Power Company
Nuclear Generation Group
One Cook Place
Bridgman, MI 49106

SUBJECT: DONALD C. COOK NUCLEAR PLANT, UNIT NOS. 1 AND 2 – CLOSEOUT OF GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (EPID L-2017-LRC-0000)

Dear Mr. Gebbie:

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 15, 2013 (ML13137A046), Indiana Michigan Power Company (I&M or the licensee) stated that it will pursue Option 2 (deterministic) for the closure of GSI-191 and GL 2004-02 for Donald C. Cook Nuclear Plant, Unit Nos. 1 and 2 (CNP).

On July 23, 2019 (Package 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 (ML19178A252 and ML19073A044 (not publicly available, proprietary information)). Following the closure of GSI-191, the NRC staff also issued review guidance for in-vessel downstream effects, "NRC Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of GL 2004-02 Responses" (ML19228A011), to support review of the GL 2004-02 responses.

The NRC staff has reviewed the licensee's responses and request for additional information 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 and containment spray system recirculation and, if necessary, take additional action to ensure system function in light of the potential for debris to adversely affect long-term core cooling. The NRC staff finds the information provided by the licensee demonstrates that debris will not inhibit the emergency core cooling system or containment spray system performance following a postulated loss-of-coolant accident. Therefore, the ability of the systems to perform their safety functions, to assure adequate long term core cooling following a design-basis accident, as required by 10 CFR 50.46, has been demonstrated.

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

Enclosed is the summary of the NRC staff's review. If you have any questions, please contact me at (301) 415-2855 or by e-mail at Scott.Wall@nrc.gov.

Sincerely,

/RA/

Scott P. Wall, Senior Project Manager
Plant Licensing Branch III
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-315 and 50-316

Enclosure:
NRC Staff Review of GL 2004-02
for Donald C. Cook Nuclear Plant,
Unit Nos. 1 and 2

cc: Listserv

U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW

OF THE DOCUMENTATION PROVIDED BY

INDIANA MICHIGAN POWER COMPANY

FOR DONALD C. COOK NUCLEAR PLANT, UNIT NOS. 1 AND 2

DOCKET NOS. 50-315 AND 50-316

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 (CTS) 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 toward the ECCS sump strainers, which are designed to prevent debris from entering the ECCS and the reactor core. If this debris were to clog the strainers and prevent coolant from entering the reactor core, containment cooling could be lost and result in core damage and containment failure.

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

Findings from research and industry operating experience raised questions concerning the adequacy of PWR sump designs. Research findings demonstrated that, compared to other

LOCAs, the 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.

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 CTS in recirculation mode at PWRs during LOCAs or other HELB accidents for which sump recirculation is required. The NRC completed its review of GSI-191 in 2002 and documented the results in a parametric study that concluded that sump clogging at PWRs was a credible concern.

GSI-191 concluded that debris clogging of sump strainers could lead to recirculation system ineffectiveness as a result of a loss of net positive suction head (NPSH) for the ECCS and CTS 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 CTS 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 requested and obtained the review and endorsement from the Committee to Review Generic Requirements (CRGR) (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 CTS 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 (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 CTS at PWRs. NRR requested and obtained the review and endorsement of the GL from the CRGR (ML040840034).

GL 2004-02 requested that addressees perform an evaluation of the ECCS and CTS 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 CTS and on the potential for additional adverse effects due to debris blockage of flow paths necessary for ECCS and CTS 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 (ML041550661), the Nuclear Energy Institute (NEI) submitted NEI 04-07, “Pressurized Water Reactor Sump Performance Evaluation Methodology” (ML050550138 and ML050550156), which describes a methodology for use by PWR licensees in the evaluation of containment sump performance. This is also called the Guidance Report (GR). 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 (ML043280641), the NRC issued an evaluation of the NEI methodology. The NRC staff concluded that the methodology, as approved in accordance with the NRC staff safety evaluation (SE), provides an acceptable overall guidance methodology for the plant-specific evaluation of the ECCS or CTS sump performance following postulated DBAs. Taken together, NEI 04-07 and the associated NRC staff SE are often referred to as the GR/SE.

In response to the NRC staff SE conclusions on NEI 04-07 “Pressurized Water Reactor Sump Performance Evaluation Methodology” (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, proprietary information), to address the effects of debris on piping systems and components (NRC Final SE at ML073520295).

- TR-WCAP-16530-NP-A, “Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191,” dated March 2008 (ML081150379), to provide a consistent approach for plants to evaluate the chemical effects that may occur post-accident in containment sump fluids (NRC Final SE at ML073521072).

- TR-WCAP-16793-NP-A, “Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid,” Revision 2, dated July 2013 (ML13239A114), to address the effects of debris on the reactor core (NRC Final SE at 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 (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 CTS will perform their intended function following any DBA. By letter dated November 21, 2007 (ML073110389), the NRC issued a revised content guide (hereafter referred to as the content guide).

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

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

Based on the interactions with stakeholders and the results of the industry testing, the NRC staff, in 2012, developed three options to resolve GSI-191. These options were documented and proposed to the Commission in SECY-12-0093, "Closure Options for Generic Safety Issue-191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance," dated July 9, 2012 (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. These will be low fiber plants with less than 15 grams of fiber per fuel assembly.

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

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

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

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

The options allowed industry alternative approaches for resolving GSI-191. The Commission issued a Staff Requirements Memorandum on December 14, 2012 (ML12349A378), approving all three options for closure of GSI-191.

By letter dated May 15, 2013 (ML13137A046), Indiana Michigan Power (I&M, the licensee) stated that they will pursue Option 2 (deterministic) for the closure of GSI-191 and GL 2004-02 for the Donald C. Cook Nuclear Plant, Units 1 and 2 (CNP-1 and CNP-2, respectively, or CNP when referring to both units).

On July 23, 2019 (Package 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 the GSI, the NRR staff issued a technical evaluation report on in-vessel downstream effects (IVDEs) (ML19178A252 and ML19073A044 (not publicly available, proprietary information)). Following the closure of GSI-191, the NRR 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" (ML19228A011).

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

GL 2004-02 CORRESPONDENCE		
DOCUMENT DATE	**ACCESSION NUMBER**	**DOCUMENT**
March 4, 2005	ML050750069	Initial Response to GL
August 31, 2005	ML052510512	Supplemental Information
December 19, 2005	ML060030459	Commitment Revision
February 9, 2006	ML060370547	2nd NRC RAI
June 27, 2007	ML072000387	Plan for Resolution
February 29, 2008	ML080770407 (Package)	Supplemental Response

August 29, 2008	ML082520026 (Package)	Supplemental Response
June 18, 2009	ML091490421	3rd NRC RAI
August 31, 2009	ML092400075	3rd NRC RAI Clarification
May 26, 2010	ML101540527	Supplemental Response
July 27, 2010	ML101960128	No Further Question Letter
May 19, 2011	ML11147A072	Additional Material Evaluation
May 15, 2103	ML13137A046	Path Forward Letter
December 18, 2013	ML13358A009	Final Disposition of Additional Material
January 20, 2022	ML22024A166 (Package)	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 CNP, in support of the resolution of GL 2004-02.

- Replaced simple geometry strainers of 85 square feet (ft^2) with complex geometry strainers of 1,972 ft^2.

- Modified recirculation sump vents to ensure debris will not adversely affect the vent function.

- Added safety-related sump level indicators.

- Installed debris interceptors to prevent debris from reaching the strainers.

- Implemented modifications to ensure water is not held up in upper containment.

- Removed problematic insulation types and reduced the number of tags and labels in containment.

- Performed downstream effects evaluation using the TR-WCAP-16406-P-A, Revision 1 methodology.

- Performed containment walk downs using the guidance of NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," April 19, 2002 (ML021490241).

- Established programmatic and procedural changes to maintain acceptable configuration and licensing basis for the sump.

- Completed an evaluation of the sump strainer function, including its effect on the ECCS and CTS pumps in accordance with NRC accepted guidance.

- Confirmed ECCS sump strainer performance by performing a prototype chemical precipitates head loss test.

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

The licensee discovered additional fibrous insulation in both CNP-1 and CNP-2 containments. The majority of this material was completely removed from the containment. Some material that would result in excessive personnel dose to remove was left in place and evaluated to be acceptable by the licensee.

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

3.0 BREAK SELECTION

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

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through February 9, 2008. The guidance documents used for the review included Regulatory Guide (RG) 1.82, “Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident”, dated November 2003 (ML033140347), and the GR/SE.

The licensee used the approved methodology as stated in the GR/SE for break selection. The postulated break location was moved along the RCS piping in 5-foot increments to determine the location which resulted in the maximum debris generation. The break locations analyzed were chosen to maximize the amount and variety of debris types generated. The initial break selection process resulted in nine potential sites as the limiting break. The limiting characteristics of break selection analyzed by the licensee include:

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

A double ended guillotine break in the primary loop piping at the Loop 4 crossover leg was concluded to be the limiting break presenting the greatest challenge to post-accident sump performance. The crossover piping is 31 inches in diameter and generated the largest total debris load that could reach the strainers. This break also resulted in the largest calcium silicate (Cal-Sil) debris amount at the strainers. This maximizes the particulate load at the strainers.

The licensee stated that the majority of insulation that could be damaged by a LOCA is reflective metal insulation (RMI). There is also a small amount of low density fiberglass (LDFG) and a moderate amount of Cal-Sil, Marinite, and Min-K.

The spectrum of breaks evaluated by the licensee is consistent with that recommended in staff-approved methodology in the GR/SE. Based on results of the limiting characteristics evaluation, the licensee determined that the break in the 31-inch diameter crossover leg in Loop 4 is the limiting break. The majority of debris generated by the various breaks is RMI which is not a major contributor to strainer head loss.

In addition to the above, secondary breaks were not considered in the break selection process. Secondary breaks were not considered because the plant licensing basis for those events do not require ECCS or CTS recirculation.

NRC Staff Conclusion

For this review area, the licensee provided sufficient information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the break selection evaluation for CNP is acceptable. 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 the postulated breaks in the RCS.

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through May 26, 2010.

The licensee provided the information specified in the content guide (identified in section 1.0 of this document), except as described in the following discussion. The licensee used the GR section 4.2.2.1.1, ZOI refinement of debris-specific spherical ZOI. The licensee used the approved methodology in the NEI 04-07 GR and the associated NRC staff SE (GR/SE) and assumed a default ZOI value of 2.0D for Transco RMI, and a ZOI value of 28.6D for their Diamond Power Mirror RMI and Min-K insulation. A ZOI of 2.0D was also assumed for their Transco LDFG insulation on the reactor vessel lower head because the encapsulating cassettes were identical to the ones containing RMI and thus would be afforded the same level of resistance to damage/destruction. A ZOI of 6.4D was assumed for the Cal-Sil insulation rather than the GR/SE default 5.45 ZOI. This ZOI size allowed the licensee to use the Alion Science and Technology (ALION) debris size distribution scheme based on the Ontario Power Generation (OPG) Test data summarized in section 3.2.2.5 of NUREG/CR-6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," dated February 2003 (ML030780733). The submittal indicated that a ZOI of 9.8D was used for the Marinite I and Marinite 36 fire barrier boards attached to cable tray sections, a ZOI of 8.2D was used for their Scotch 77 fire barrier tape applied to rigid electrical conduit, and a ZOI of 6.0D was used for their Electromark Series 1000 labels (plastic sheet adhered to stainless steel sheet backing) based on testing and evaluations documented in Wyle Laboratories Test Report 54497R07, Revision B, "Jet Impingement Test of Electromark Labels and Thermal and Fire Barrier Insulation" and Sargent & Lundy Report SL-009195, Revision 0, "Wyle Jet Impingement Testing Data Evaluation." Neither of these reports were reviewed by the NRC staff.

The submittal indicated that service water piping inside the crane wall could potentially be impacted by a line break and was covered with Rubatex closed cell foam insulation glued to the piping, jacketed with stainless steel, and banded. As Rubatex is no longer available a virtually identical Armacel Armaflex insulation was identified as the acceptable replacement and was tested by Wyle Laboratories. The testing data and evaluation are included in the previously identified reports. As a result of the testing the CNP design standard/specification for this insulation system was changed to require double jacketing and prohibit the use of a moisture barrier plastic backing on the jackets. The submittal indicated that these configuration changes would be implemented by the end of the CNP-1 Spring 2008 refueling outage. The licensee stated that as a result, this insulation system (Rubatex/Armaflex) is not considered a potential debris source because it is "not located immediately adjacent to postulated break locations." No ZOI was identified in the submittal for this insulation system.

The submittal listed the bounding quantity of labels, fire barrier tape, flexible conduit PVC jacketing, ice storage bag liner shards, and work platform rubber residual material that could transport to the strainers. These categories summed to 137.44 ft^2. A sacrificial area of 76 ft^2 was assigned to the main strainer and 83 ft^2 to the remote strainer.

RAI Review

On June 18, 2009, the NRC issued RAIs requesting the licensee to identify the ZOI used for the Rubatex/Armaflex insulation material and to state whether there were any potential break locations that could result in damage to the material. The licensee stated that the testing and methodology that was initially used to determine the ZOI for the insulation systems was determined to be faulty. The licensee recalculated the ZOI for the double jacketed system and determined that no damage would occur outside of 5.9D.

The NRC staff reviewed the licensee's response of May 26, 2010, and determined that the licensee had appropriately considered the issues with the initial ZOI methodology for the insulation system. The NRC also considered that it would be unlikely for the Rubatex or Armatex to create significant blockage on the strainer because it would float throughout the event and not be able to collect on the strainer once it was fully submerged. The NRC staff also considered that the licensee's sacrificial strainer area was conservative and that the limiting breaks were further from the material making it less likely for debris generation from this source when considering the breaks that generate the largest quantity of other debris types.

NRC Staff Conclusion

For the debris generation/ZOI evaluation, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the debris generation/ZOI evaluation for CNP is acceptable. The NRC staff considers this area 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 May 26, 2010.

The licensee provided an extremely detailed response that generally addressed the information request in the content guide. The NRC staff generally considered the licensee's debris characteristics assumptions to be consistent with regulatory guidance. However, a number of custom approaches were taken to achieve refinements to the approved guidance such that RAIs were generated to ensure that the NRC staff understands the refinements.

The licensee's supplemental response identified the applicable debris types at CNP as including stainless RMI, Cal-Sil, Marinite, Min-K, various qualified and unqualified coatings, latent fiber and particulate, labels, and other miscellaneous debris. The licensee stated that the size distributions recommended in NEI 04-07 were used for the materials with the exceptions of Marinite, Cal-Sil, coatings, and several other miscellaneous types of debris including Scotch 77 fire retardant tape, Electromark labels, and ice condenser debris. Of these, the treatment of Marinite and Cal-Sil were considered by the NRC staff to be significant enough to warrant RAIs.

RAI REVIEW:

On June 18, 2009, the NRC staff issued RAIs requesting that the licensee provide information regarding the scaling process during the testing and evaluation of various material debris characteristics. The NRC staff were concerned that the test jet may not have exposed the test articles fully to the intended pressure. The NRC staff also requested more specific information on the tests used to determine the Marinite size distribution. Finally, the NRC requested the licensee to compare its Cal-Sil to the Cal-Sil used in the test referenced by the licensee to determine the Cal-Sil characteristics.

The licensee responded to the RAIs by providing additional information and pictures regarding the testing and methodology used to determine the debris characteristics. The licensee also identified the tests used for Marinite characterization. The licensee stated that the test rig was determined to have a choke point upstream of the nozzle which could reduce the energy of the jet. The licensee revised its characterization of materials to compensate for this issue. The ZOIs for Marinite and fire barrier tape were increased from about 9D to 17D and the ZOI for Electromark labels was increased from 6D to 9.9D. The licensee also characterized the Marinite failures during the test as caused by deformation of the cable tray in the testing. The licensee stated that the Marinite installed in the plant had additional structural support that would not allow the material to fail as it had in the test. The licensee also referenced NUREG/CR-6772, "GSI-191: Separate-Effects Characterization of Debris Transport in Water," dated August 2002 (ML022410104) that established a destruction pressure of 64 pounds per square inch gauge (psig) (about 3D) for Marinite. The licensee stated that the Marinite closest to the bounding break is 5.9D from the break location. The licensee also discussed the testing of Electromark labels, fire barrier tape, and Armaflex. The licensee stated that the testing and evaluation of these materials provided an adequate estimation of the debris characteristics or that the debris sources were outside the zone where they could be damaged.

The NRC staff reviewed the licensee's analysis and determined that it was acceptable based on the following. The NRC staff considers it conservative that the licensee used 17D ZOIs for the Marinite and fire barrier tape, along with limiting debris characterization results from much smaller ZOIs.

For the Marinite, the licensee further stated that NEI 04-07 also includes the position that the destroyed pieces would likely be in the form of chunks rather than fine powder. The NRC staff further had confidence in the appropriateness of the assumption for Marinite because much of the Marinite is not in close proximity to breaks and would not be exposed to high jet pressures capable of causing significant damage. The NRC staff found the claim that the testing of the fire barrier tape was not affected by the choke point upstream of the nozzle to be non-conservative. However, this non-conservatism is mitigated by the use of a 17D ZOI.

Although the NRC staff expects that the double jacketing on the Armaflex insulation would provide substantial protection from jet impingement, it is not clear to the NRC staff whether the licensee's Armaflex ZOI is valid. However, the Armaflex material tends to float following a LOCA, and is not considered a highly problematic material. Finally, the NRC staff noted that all the items at issue in this question, Marinite, fire barrier tape, Armaflex, and labels, are not items that experience has shown to be very problematic in debris generation and head loss for strainers. The NRC staff also determine that the licensee has a significant margin in the overall quantities of debris that were used for strainer testing. Therefore, although some uncertainties remain on specific technical items regarding debris characterization, the NRC staff considers this RAI to have been addressed.

The licensee stated that the Cal-Sil at CNP is Johns-Manville Thermo-Gold 12. The licensee stated this is the same material used for OPG testing, as well as for Alion erosion testing. The licensee also compared the plant jacketing and banding to the OPG testing. The licensee indicated that some installations (e.g., approximately 45 percent-60 percent) would allow a maximum band spacing of 12 inches. The licensee also indicated that the plant piping is slightly larger, and the insulation is thicker than that in the test.

The information provided by the licensee demonstrated that the Cal-Sil base material at CNP is similar to the materials tested for debris generation and erosion. Although there is some uncertainty in the differences between the plant and test insulation system configurations, the NRC staff determined that there is significant conservatism in the licensee's particulate source term that would account for slight increases in the amount of fine Cal-Sil produced by a LOCA jet.

NRC Staff Conclusion

The licensee used debris characteristics the meet staff guidance or demonstrated that the characteristics used in their evaluation are reasonable. The analysis contains significant margin. Therefore, the NRC staff concludes that the debris characteristics evaluation for CNP 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 August 28, 2008.

The licensee provided the methodology used to estimate quantity and composition of latent debris and the basis for assumptions used in the evaluation. The licensee also provided the results of the latent debris evaluation. The licensee provided the amount of sacrificial strainer surface area allotted to miscellaneous latent debris. The licensee implemented a sampling methodology during two outages each for CNP-1 and CNP-2. The horizontal surface debris was measured and the vertical surface debris was estimated. The highest total debris amount from the four sample sets was less than 180 pounds (lbs.). The licensee assumed a bounding value of 200 lbs. of latent debris for each unit for purpose of analysis and testing. The calculation for determination of latent debris loads was conservatively developed to overestimate the surface areas of floors, major equipment, and piping and conduit. An additional conservatism applied to the results was that the sampling occurred prior to the concentrated effort to clean containment near the end of the Fall 2006 CNP-1 RFO and the Fall 2007 CNP-2 RFO.

The assumed 200 lbs. of latent debris adds a measure of conservatism to the totals shown in the above table. The latent debris was taken as 15 percent fiber and 85 percent particulate, which is acceptable based upon the NRC SE.

The methodology for sample measurement and calculation was found to be reasonable.

The licensee presented the total surface area of labels, tape and other miscellaneous debris found in containment. For the main strainer, 76 ft^2, and for the remote strainer 83 ft^2, were assigned as sacrificial areas. These quantities are stated to be conservative by the licensee, based on data collection completed in CNP-2 combined with debris transport fractions. Using the provisions of section 3.5.2.2.2 of the SE, the assumed effective CNP-2 strainer area blocked for the main strainer is (0.75)(20.68 ft^2) = 15.51 ft^2 and for the remote strainer is (0.75)(32.41 ft^2) = 24.31 ft^2. Based on data collection completed in CNP-1 combined with debris transport fractions, 23.03 ft^2 of material is available for potential blockage of the main strainer, and 33.50 ft^2 of material is available for potential blockage of the remote strainer. Using the provisions of section 3.5.2.2.2 of the SE, the assumed effective CNP-1 strainer area blocked for the main strainer is (0.75)(23.03 ft^2) = 17.27 ft^2 and for the remote strainer is (0.75)(33.50 ft^2) = 25.13 ft^2.

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

NRC Staff Conclusion

The NRC staff considers the latent debris area to be adequately evaluated by the licensee. Therefore, the NRC staff concludes that the latent debris evaluation for CNP 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 26, 2010.

The licensee provided a detailed response that generally addressed the information request in the content guide. Many of the licensee's assumptions and methodologies were consistent with the approved guidance; however, the licensee made several critical assumptions or refinements that did not have an adequate technical basis. In particular, the NRC staff did not agree that the licensee adequately analyzed the pool-fill phase of the LOCA and other time-dependent aspects of the transport calculation that were used as a basis for conducting large-scale head loss testing.

The licensee stated the transport analysis followed the NEI 04-07 guidance, as modified by the NRC staff's SE, considering blowdown, washdown, pool fill up, and recirculation phases of the accident. Logic trees were used to quantify debris transport.

Blowdown: The licensee assumed that blowdown of fines would be distributed in proportion to the distribution of mass and energy from the pipe rupture, 70 percent to the ice condenser, 22 percent to the annulus, and 8 percent to the reactor cavity. None of the large or small pieces of debris were assumed to be blown into the ice condenser or reactor cavity, obviating any credit for retention in these locations. Five percent of small pieces were considered to be blown into the annulus, given geometric obstacles and intervening structures.

Washdown: All debris assumed to transport to the ice condensers was assumed to be washed back down again. Failed coatings in upper containment were assumed to be washed down by sprays in upper containment. Thus, no retention of debris appeared to be credited in upper containment or ice condensers.

Pool Fill Up: 8 percent of fines (that were created by the pipe rupture) were assumed to be captured in the reactor cavity. A computational fluid dynamics (CFD) analysis of pool fill up was performed for CNP using the FLUENT CFD code. Modeling flows during this period is significantly more complicated than during recirculation.

Recirculation: The licensee also used the FLUENT code to compute the flow pattern in the containment pool. The licensee provided a thorough description of how most aspects of the calculation were performed, including flow resistance calculations, drainage locations, sump flow splits, etc.

The NRC staff identified some minor issues with the transport methodology used by the licensee, but they resulted in little or no change in the results of the transport evaluation. These minor issues are not discussed here.

The licensee reported debris transport fractions in a table in its supplemental response. The overall transport percentages appear conservative or reasonable based on the descriptions provided and the NRC staff's engineering judgment. Many of the values are greater than 100 percent. The basis for this calculation was not clearly explained but is obviously conservative.

Despite the overall conservative results, the NRC staff has concerns that the licensee does not have an adequate basis underlying the distribution of this debris to the main and remote strainers. The licensee's determination was made based on a number of assumptions that the NRC staff does not consider representative of the likely post-accident conditions in containment, including the following:

- Water draining into the containment pool during the pool-fill-up phase is assumed to be clean. However, debris would be washing into the containment pool during this time via the flows from the break, sprays, and melted ice.
- The flow rate into the containment pool is assumed to be equal to the flow rate out of the pool into the reactor cavity; however, if this assumption were valid, then the pool level should never increase.
- The flow split between the remote and main strainers during pool-fill up appears to be based upon the assumption that negligible flow resistance is present at the main strainer. Since the perforations in the debris interceptor at the overflow wall are 1/2 inch rather than 1/12-inch, debris will preferentially block the main strainer and result in more of the flow during pool fill being diverted into the annulus than assumed by the licensee.
- The behavior of water draining from the break, sprays, and ice melt into the containment pool during the pool-fill phase has a significant effect on the flow pattern that is very difficult to model accurately. The licensee stated that it was conservative to use values of velocity and turbulence from the 300 second time step to compute debris transport. It is likely that these values underrepresent values at earlier times.
- The modeling of drainage sources was not discussed with sufficient detail. Particularly, drainage from the refueling canal and ice condenser were not adequately evaluated.
- The licensee did not model the flow resistance of the main strainer during the recirculation phase of the LOCA. Rather, the main strainer was assumed to be 90 percent blocked for the maximum transport case. No basis was presented for this assumption, and it appears arbitrary. Even with 90 percent blockage assumed, the flow through the main strainer still ends up being significantly higher than the flow through the remote strainer (9,720 gallons per minute (gpm) to 4,680 gpm), for which no flow resistance is modeled. This blockage assumption, regardless of the amount of debris accumulated on the strainer, increases the tendency for non-uniformity between the main and remote strainers, thereby reducing the overall system head loss in a way that does not represent the plant condition. This arbitrary assumption underlies the distribution of debris used in the licensee's head loss testing and is therefore an important issue.

The licensee assumed that small pieces of debris would not be in the vicinity of the strainers at the beginning of recirculation. An adequate basis was not provided to support this distribution. During the pool-fill-up phase, based on the CFD, there appears to be sufficient energy in the containment pool flow to transport small pieces of debris into the vicinity of the strainers. The NRC staff determined that this issue did not warrant an RAI because of the reduced significance of small pieces compared to fines.

The NRC staff also identified concerns with the licensee's use of transport insights in the head loss testing. The concern is that the head loss test may have been conducted with unrealistic water levels during the formation of the debris bed in the fill-up phase. The local approach velocity during bed formation was likely lower than would be expected in the containment pool, since the shallow pool depth would result in a smaller vertical cross section that would lead to increased velocities for a given flow rate.

The licensee stated that erosion testing was performed for Cal-Sil and Marinite board. Testing was performed on materials supplied by plant and stated to be the same as those installed in the plant. It was not clear that both dissolution and erosions were considered in this testing. The NRC staff requested additional information in the following areas discussed below.

In RAI 5, the NRC staff requested that the licensee provide the basis for considering the Loop 4 break to be bounding, not only from the standpoint of transporting the greatest quantity of problematic debris, but also from the standpoint of the degree of uniformity in the debris distribution between the main and remote strainers.

One of the fundamental arguments made by the licensee regarding the debris transport to the two strainers was based on the computation of system head loss along the separate flowpaths from the main and remote strainers. This argument included consideration of the clean strainer and debris bed head loss contributions and provided head loss curves that attempted to examine the effect of varying the flow and debris balance between the main and remote strainers. The second fundamental argument made by the licensee was that the amounts of debris tested on each strainer were sufficiently conservative relative to the total quantity of debris that is analyzed as transporting to both of the strainers. The licensee provided tables and charts to demonstrate this argument.

The NRC staff disagrees with the licensee's first fundamental argument in its response to RAI 5. The transport of debris was based on the head loss along the flow paths to each strainer. The argument is ultimately based on unvalidated assumptions concerning the flow resistance of the main and remote strainers. Debris transport behavior during blowdown, washdown, and pool-fill is highly variable and chaotic, and the debris split between the two strainers is a random variable ultimately dependent on these chaotic phenomena. Additionally, the analysis performed by the licensee makes use of the head loss testing results. This results in circular logic because each is dependent on the other thereby adding uncertainty to the analysis which already included uncertainties. The NRC staff agrees with the licensee's second fundamental argument. Based on a comparison of the debris loadings per strainer surface area available in various analyzed cases to the corresponding quantities tested, it is apparent that the testing bounded all reasonable debris loads that could arrive at either strainer. This was because the final analyzed debris loadings were reduced significantly from the loads used during strainer testing. Because the testing covered the range of potential debris loadings for both strainers, the NRC staff considers this issue closed.

In RAI 6, the NRC staff requested the licensee to provide the basis for certain assumptions made in the debris transport analysis when deriving the flow and debris distributions between the main and remote strainers. First, the NRC staff requested a basis for the assumption that the flow resistance of the main strainer is negligible during pool fill even though debris is assumed to collect on the strainer and the only driving force through the strainer and debris is static head. The second NRC question was associated with the assumption that ten percent of the area of the main strainer is assumed to remain clean during recirculation. This assumption was maintained even though large-scale test results suggested a degree of flow resistance consistent with the formation of a debris bed over the entire strainer flow area. Also, other head loss tests on a variety of different strainer geometries demonstrated that a debris bed may form over the entire strainer surface area rather than leaving part of the strainer area open. The third assumption questioned by the NRC staff was that water draining into the containment pool during the fill-up phase was assumed to be clean. Overall, the NRC staff did not consider the flow and debris distributions to the main and remote strainers to be adequately justified.

In response to RAI 6 the licensee stated that head loss testing showed that the quantity of pool fill debris on the main strainer did not cause a significant increase in head loss, and therefore would not result in a significant shift of flow and debris to the remote strainer. The licensee also responded that the debris bed on the main strainer resulted in a head loss equivalent to a reduction of the clean strainer area by approximately 96 percent.

From a debris transport perspective, the licensee stated that, as the main strainer becomes blocked beyond 90 percent, the flow and debris tend to be directed more towards the remote strainer. The licensee stated that no hold up of fiber and debris was taken along the path to the remote strainer, although significant settlement would likely occur. The licensee also stated that there is significant margin between the quantity of debris tested and the quantity that was analyzed. The licensee acknowledged uncertainties with modeling non-recirculation transport but did not consider them significant to this question. The licensee stated that debris blown to the ice condensers would be immediately washed back into the containment pool, as 80,000 gallons of water washes back into the containment pool in 15 seconds, and that additional ice melt would be essentially clean. The licensee stated that unqualified coatings, latent debris, and other miscellaneous debris were assumed to fail or wash down more gradually during the recirculation phase. The licensee acknowledged washdown would not be perfectly clean but considered its evaluation reasonable.

The NRC staff did not agree with the licensee's technical response to this RAI. The NRC staff did not consider the licensee's testing to have been an adequate representation of pool fill behavior because the testing was not performed with representative water levels of the pool fill phase and the driving flow was not representative of simple gravitational static head. Therefore, the approach velocities and debris bed formation on the strainer surface were not representative. For the second part of the RAI this same discussion is also true. Therefore, the NRC staff does not accept the licensee's argument concerning the percentage of strainer area effectively blocked off by debris. The NRC staff agrees with the licensee's statement that more debris was tested than was analyzed as transporting, as discussed in RAI 5. For the final part of the RAI, the NRC staff expects that ice condensers would wash down a significant fraction of debris that reaches the ice condensers, but it isn't clear how much debris will be able to reach the ice condensers to be washed down immediately with that flow. This is highly break dependent. While some debris would certainly follow the flow of pressurized gas into the ice condensers, structures and changes in direction would prevent significant quantities of debris from reaching the ice condensers. The NRC staff considers the assumption that all debris washes down prior to pool-fill as clearly unrealistic and non-conservative in this case where there are multiple strainers with non-uniform debris loadings. However, based on the discussion in RAI 5 that covers the excess debris that the licensee used for strainer testing, the NRC staff also considers RAI 6 to be closed.

In RAI 7, the NRC staff requested the licensee to provide additional information concerning the erosion testing of Cal-Sil insulation and Marinite board including not considering dissolution in the testing, not including buffer materials in the testing, using a relatively low velocity during the testing, and not considering the turbulence conditions in the testing.

The licensee described the testing and associated test reports, and also provided a graph of the erosion test results. The licensee also argued that dissolution was a different mechanism than erosion and would be negligible and provided information to support this view. The licensee stated that some testing was done at plant pH and temperature conditions, but the material did not seem to be strongly affected. The licensee stated that buffer was not added to the final testing, and that reverse osmosis water was used to avoid contaminating the samples. The licensee also stated that the average velocity in the non-transporting region for Cal-Sil and Marinite were 0.11 feet per second (ft/sec) for small pieces of Cal-Sil and 0.18 ft/sec for large pieces of Marinite. The licensee stated these velocities are significantly less than the velocity used during testing. Finally, the licensee stated that the turbulence will vary during different phases of the event.

The licensee also stated that the effects of turbulence during the initial pool-fill phase will be negligible because it occurs for a very short time (about 20 minutes) compared to the 30-day mission time.

The NRC staff considered the licensee's response to be conservative and acceptable. In reality, it is expected that the erosion rate for Cal-Sil and other materials would decrease with time, rather than remaining constant as assumed by the linear extrapolation technique used by the licensee. Largely on the basis of the conservative analysis of the test data, the NRC staff considers the response to this RAI to be acceptable. The NRC staff also agrees to some degree with the licensee's responses to detailed aspects of this question discussed above. Any uncertainties remaining are considered bounding compared to the conservatism associated with the linear extrapolation of the test results. Therefore, the response to RAI 7 is acceptable.

In RAI 8, the NRC staff requested the licensee to provide the basis for the assumed Cal-Sil tumbling transport velocity metrics for small and large pieces, and state whether these metrics were based on measurements of incipient tumbling, bulk tumbling, or some other criterion.

The licensee stated that the small- and large-piece tumbling velocities assumed for CNP were based on flume testing performed by Alion. The licensee stated that the velocities used were incipient tumbling velocities and that the Cal-Sil metrics were applied to Marinite as well. The licensee stated that the tumbling velocities cited in NUREG/CR-6772 for 1-inch chunks were very similar to the values determined in the Alion testing. The licensee concluded that a value of 0.33 ft/sec was acceptable for small pieces of Cal-Sil for CNP because OPG testing showed that most of the pieces were in the 1- to 3-inch range rather than less than 1 inch.

The licensee provided the requested information in the question and a test basis was identified for the licensee's tumbling velocity metrics. For similarly sized pieces, the licensee's testing aligns relatively well with the NUREG/CR-6772 test results that were sponsored by the NRC. Based on the observation that most of the destroyed Cal-Sil was in the range of 1- to 3-inch pieces, and the metric for 1-inch pieces was used and the fact that the same metrics were used for Cal-Sil and Marinite (which is typically denser and less transportable) the NRC staff accepted the response to RAI 8. The NRC also noted that the licensee has significant margin between the amount of Cal-Sil tested and the amount analyzed to reach the strainers. Therefore, the NRC staff considered the response to RAI 8 to be acceptable.

In RAI 9, the NRC staff requested that the licensee clarify how debris transport percentages greater than 100 percent for a number of debris types were computed, to the extent these percentages are credited as conservatisms in its transport calculations

The licensee's response acknowledged the potential for confusion in the February 2008 supplemental response concerning how to compute the transport fractions. The licensee provided an example regarding the latent debris that showed by referencing tables in the head loss section of the response that the quantity of debris tested was equivalent to more than 100 percent transport.

The NRC staff concluded that the licensee's response to this RAI is not very clear. However, discussion in other parts of the response provides sufficient confidence that the debris quantities tested by the licensee exceed the quantity of debris that the licensee has analyzed as reaching the strainers. See the discussion in response to RAI 5. Therefore, the response to RAI 9 is acceptable.

NRC Staff Conclusion

For the transport area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the debris transport evaluation for CNP is acceptable. 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.

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through May 26, 2010.

The licensee's approach to reducing strainer head loss is to install two passive Components Control Incorporated (CCI) strainers in each unit. The licensee provided the information regarding the strainer and the head loss analysis as summarized in the next few paragraphs. There is a main strainer installed inside the bioshield wall and a remote strainer installed outside the crane wall. The main strainer discharges directly into the sump while the remote strainer discharges into a sealed duct that passes through the crane wall and discharges into the same sump as the main strainer. The new strainer areas total 1,972 ft^2 per unit. About 900 ft^2 is allotted to the main strainer in the RCS loop compartment, and about 1,072 ft^2 is installed as the remote strainer outside the crane wall. The fibrous debris available to the strainer comes only from latent fiber. Both units' containments contain significant amounts of Cal-Sil insulation. The flow through the strainer is stated to be about 14,400 gpm. The corresponding average approach velocity is about 0.0163 ft/sec, however, the evaluation stated that more flow per unit area was expected through the remote strainer because the main strainer will become more heavily loaded with debris. This is partially offset by the head loss that occurs through the waterway or duct that connects the remote strainer to the sump.

The licensee stated that the design limit for strainer head loss is 2.8 ft. This limit is based on margin to vortexing of the ECCS and CS pumps. Vortexing is a concern because the sump is vented so any head loss will tend to reduce the water level downstream of the sump. Without the vortexing concern, the NPSH and structural margins associated with the strainer are much higher.

Because of the relatively complex issues associated with debris transport and clean strainer head loss (CSHL), the licensee performed several calculations to determine the overall system head loss. The CSHL was calculated to be about 0.05 ft. However, this is misleading because the CSHL associated with the main strainer is almost zero, while the CSHL associated with the remote strainer and the waterway that connects it to the sump is somewhat higher. The CSHL associated with the remote strainer and waterway varies proportionally to the flow through it. The flow split between the strainers depends on the relative debris loading of the two strainers. The CSHL for the remote strainer (including the waterway) is about 0.278 ft at 50 percent flow and about 1.105 ft at 100 percent flow. The actual CSHL for the remote strainer would likely be somewhere between these two values depending on the relative loading of the two strainers.

The final head loss calculation found the total system head loss to be about 12.5 inches with the waterway CSHL about 3.9 inches. CNP multiplied the result of the final head loss calculation by 1.5 for conservatism and margin, and to address the uncertainty caused by the strainer arrangement. The final overall strainer head loss without chemical effects was calculated to be 1.57 ft. This head loss did not account for potential chemical effects.

The chemical effects test was performed only for the main strainer area. To extrapolate the results of the chemical effects testing to the main and remote strainers, a bump-up factor was applied to the overall system head loss determined in the non-chemical head loss testing. It was noted that the non-chemical debris head losses during the testing were somewhat higher than earlier non-chemical test head losses. This is probably due to the higher flow rate through the strainer during the chemical effects testing. The head loss with chemical effects added was about 1.5 times higher than the non-chemical head losses in the test. CNP applied a bump-up factor of 1.7 which resulted in a final head loss of 2.67 ft. Although the NRC staff has questioned the use of a bump-up factor in the past, CNP's application is considered acceptable because the chemical effects testing was conducted on a prototypical strainer with prototypical debris loads. The bump-up factor was determined with a conservative flow rate and was increased to add margin.

The submittal also stated that the main strainer is fully submerged by at least 21 inches at the onset of recirculation during a small break LOCA. The submergence decreases to 1.2 inches later in the event. For a large break LOCA (LBLOCA) the minimum submergence is about 11 inches. The submergence of the remote strainer is about 5 inches greater than the main strainer.

The CNP sumps are fully vented to the atmosphere above the minimum containment water level.

The strainer arrangement makes the evaluation of debris loading on the two separate strainers more complex than it is for most plants. The head loss review was coordinated closely with the transport review to ensure that the analyses were consistent and met staff guidance. The complexity of the analyses caused the NRC staff to request significant additional information from the licensee to ensure understanding.

On June 18, 2009, the NRC issued RAIs including those discussed below regarding the head loss and vortexing evaluation.

In RAIs 10, 11, and 12, the NRC staff requested information that justified that the debris was prepared and added to the test so that a debris bed that is prototypical or conservative with respect to one that would form in the plant was created during testing. The licensee responded that the methods used for preparation and addition of debris resulted in a debris distribution that was relatively uniform over the surface of the entire strainer. The licensee provided the procedure used for creating the fibrous debris from the intact material and stated that the debris was prepared as fines and diluted prior to addition to prevent agglomeration and settling. The licensee stated that the fibrous debris for the large flume test was prepared in the same manner as that for the multifunctional test loop (MFTL). The licensee also cited flow measurements, taken over the height of the strainer, as being relatively uniform which further indicated that distribution was uniform. In addition, the licensee observed very little debris settlement in the test flume at the test conclusion indicating that excessive settling did not occur. Photographs of the fibrous debris in solution and of the debris addition were provided.

The photographs indicate that the debris preparation and introduction resulted in adequately fine, non-agglomerated debris. Based on the licensee description of the debris preparation and addition methods and photographic evidence, the NRC staff concludes that the debris preparation practices used during testing met staff guidance. Note that the NRC staff has also visited CCI to witness testing and found the debris preparation and addition methods used in the multifunctional test loop to be satisfactory. Also, visual and flow evidence that the debris bed was relatively uniform allows the NRC staff to conclude that the head losses attained during the test were not affected non-conservatively by the debris preparation. Therefore, the NRC staff finds the response to RAIs 10, 11, and 12, acceptable.

In RAI 13, the NRC staff requested that the licensee justify that the RMI would actually transport into the upper strainer pockets as was observed in post-test photographs of the MTFL testing, or that the inclusion of the RMI in the head loss testing did not affect the test non-conservatively. The licensee stated that the RMI distribution in the test was likely non-prototypical but did not affect the resulting head loss non-conservatively. The licensee stated that the test in which the RMI transported into the strainer pockets was not intended to determine the bounding head loss value but was intended to determine the effects of chemical precipitates on the head loss. The response stated that the RMI did not affect the results of the test because it did not affect the ability of the chemical precipitate to reach and penetrate the fiber-particulate debris bed. The licensee cited photographic evidence provided in an earlier submittal to validate this claim. The licensee stated that the chemical effects test included a conservative amount of fibrous and particulate debris which would result in conservative head loss values. During a phone call with the NRC staff, the licensee stated that the fibrous and particulate debris was added prior to the RMI debris. The NRC staff agrees that the MTFL test contained more debris than is representative of the average debris load over the entire CNP strainer surface and that this would result in a conservative head loss value. The NRC staff also reviewed the licensee supplemental response to validate that a filtering bed had formed and that the addition of RMI to the test did not prevent the bed from forming or disturb the debris bed. Because the fibrous and particulate debris formed a filtering bed and the chemical precipitate was verified to reach and penetrate the debris bed, the NRC staff concluded that the test provides an adequate basis for estimating the effects of chemical precipitates on strainer head loss. The response to RAI 13 is acceptable.

In RAI 14, the NRC staff requested that the licensee justify that the practice of starting the head loss test with flow rates less than those representing 100 percent scaled flow, and the practice of batching debris, including RMI, at these lower flow rates did not affect the results of the head loss testing non-conservatively. The response to RAI 14 stated that the licensee did not believe that the NRC staff understood the test methodologies as described in the supplemental response. The licensee stated that some of the testing (event sequence testing) was modeled to represent the pool-fill flow through the main strainer and then flow was increased to represent full ECCS flow through both strainers. For the standard head loss testing, the licensee stated that flow rates were established followed by debris addition in steps of 60 percent, 80 percent, and 100 percent. The licensee stated that the flow rate to the main strainer will change as a function of time. The response further stated that since debris settlement was not credited during testing and a uniform debris bed was created, that the debris bed that formed would be conservative and the bed compression expected at 100 percent plant flow would occur when the test flow rate was increased to 100 percent. The licensee also stated that during the pool fill phase that debris could only enter the pockets up to the level that water had reached, and that debris would therefore be distributed more heavily to the bottom pockets of the main strainer. The licensee stated that the debris addition methods used resulted in a more uniform debris bed and therefore a higher head loss than would be expected in the plant.

The licensee also stated that significantly more debris than is expected to arrive at the strainer was included in the testing and referenced the response to RAI 5 for further discussion of this matter. The NRC staff agrees that testing was conducted with margin in the debris loading. The NRC staff agrees that as long as a uniform debris bed was formed over the surface of the strainer and the flow rate was increased to 100 percent of the scaled plant design flow rate that a conservative or representative head loss will be attained during testing. Since the licensee used a conservative debris load, created a uniform bed during testing, and measured the limiting head loss at 100 percent scaled flow, the NRC staff has confidence that testing resulted in a reasonably bounding head loss for CNP. The response to RAI 14 is acceptable.

In RAI 15, the NRC staff requested information regarding the reasons that different test sequences resulted in different magnitudes of head loss results for similar debris loads. The licensee responded that there are numerous factors that can affect the head loss during strainer testing. The licensee postulated that because the testing was conducted with two separate strainer sections (sides) which represented the main and remote strainers in the plant, that one side of the strainer could be more heavily loaded than the other. A slight imbalance in loading can affect the overall head loss. The licensee also postulated that because the strainer is designed to form a non-uniform debris bed, that even though the testing was designed to result in a uniform debris bed, that some differences in the debris bed occurred between tests. The licensee stated that because of these phenomena and the variability inherent in head loss testing that the highest head loss attained during testing was selected as the design basis head loss. The NRC staff accepts that the licensee's evaluation of the reasons for differences in the head loss testing results is potentially valid. The NRC staff is also aware that head loss test results, even under controlled conditions can vary. The licensee's test protocol added some complexity to the test by modeling the effects of pool fill on the main strainer for some tests and by modeling the main and remote strainer separately. Because of the added complexity, the NRC staff concluded that some larger than typical variation in test results would be expected. Based on the licensee's use of conservative debris loads in the testing and selection of the highest head loss value from the tests as the strainer design head loss, the NRC staff concludes that a reasonably conservative and bounding head loss for the strainer was determined by the test program. The response to RAI 15 is acceptable.

In RAI 16(a), the NRC staff requested that the licensee provide an explanation for why the non-chemical head losses were higher during the chemical testing than during the earlier non-chemical tests. The licensee stated that the chemical effects testing was conducted with the scaled equivalent area of the main strainer only and that the remote strainer area was not included. The testing included debris loading which cannot be compared directly to the testing that included the remote strainer. Based on a review of the test debris loading and flow rates that were used during the various tests the NRC staff concluded that it would be likely that the head loss for the non-chemical portion of the chemical effects testing would be higher than the head loss during the non-chemical testing. For example, the flow rate through the modeled main strainer during chemical testing represented about 67 percent of the flow through both the main and remote strainers, yet the main strainer area is smaller than the remote strainer area. The fibrous debris loading on the main strainer also represented greater than 50 percent of the total fibrous debris in the plant. The NRC staff finds the response to RAI 16(a) acceptable.

In RAI 16(b), the NRC staff requested that the licensee provide justification that the pre-chemical head loss, which was observed to be higher than the head loss during earlier non-chemical testing, would not result in a reduced bump-up factor based on the chemical effects testing.

The licensee performed a review of chemical effects testing that had been conducted for other strainers using the CCI pocket design and compared only low fiber plants similar to CNP. Based on the reviews of these other test, the licensee concluded that a higher initial head loss does not necessarily correspond to a lower chemical effects head loss. The higher initial head loss is indicative of a more compact filtering bed which would tend to remove more chemical debris than a more porous bed. Because there is some uncertainty in the chemical bump-up methodology, the licensee increased the bump-up factor to add margin in the head loss evaluation. The NRC staff reviewed the test conditions of the CNP testing and the comparison between the CNP and other licensee testing. Based on the review, the NRC staff concluded that the bump-up factor determined by the licensee is a reasonable bounding value for what would be expected to occur in the plant. The NRC staff also recognizes that the licensee performed two chemical effects tests, used the higher bump-up factor from the tests, and added margin to the higher value to account for uncertainties in the methodology. Although the NRC staff could not determine whether the bump-up factor was conservative or not, the methodology described above and the comparison to other tests provides a basis for the NRC staff to conclude that a reasonably bounding value was used in the CNP evaluation. Based on the above the NRC staff finds the response to RAI 16(b) acceptable.

In RAI 16(c), the NRC staff requested that the licensee provide justification for not applying the results of the chemical effects testing directly to the applicable plant evaluations. The licensee referenced the response to RAI 16(a) which stated that the chemical testing was performed with significantly conservative debris loads. The NRC staff evaluation of RAI 16(a) also applies to RAI 16(c). The debris loads and flow rates in the chemical effects testing were significantly conservative compared to the same variables in the non-chemical testing. Use of these values for the overall head loss value could be overly conservative. The response to RAI 16(c) is acceptable.

In RAI 17, the NRC staff requested that the licensee provide the sensitivity of strainer system head loss to differences in debris transport to each strainer. The licensee referenced the response to RAI 5. In response to RAI 5, the licensee presented a model of the strainer system comprised of the main and remote strainers and the duct that connects the two strainers. The licensee also provided details regarding the plant layout, anticipated debris transport phenomenon, and the testing methodology and inputs. The licensee also showed that the testing included significant margin for all debris types, including about 30 percent margin for fine fibrous debris, 100 percent margin for particulate and 50 percent margin for problematic debris like Cal-Sil. The NRC staff did not accept the sensitivity evaluations presented in the response to RAI 5 as valid. However, based on the significant margins in the debris loads for the testing, the NRC staff concluded that the testing bounded any reasonable debris transport scenario and that the head loss testing was conducted with significantly conservative debris loading. The NRC staff concluded that the conservatism in the debris loading resulted in the use of head loss values in the evaluation that bounded any reasonable debris distribution on the strainer. Therefore, the response to RAI 17 is acceptable.

In RAI 18, the NRC staff requested that the licensee provide the total head loss, including CSHL, or confirm that the total head loss value reported included the CSHL portion. The licensee stated that the reported head loss values included CSHL. The licensee further stated that they would no longer be using a 50 percent increase factor to account for uncertainties in the head loss evaluation. The 50 percent value was noted to be overly conservative and was no longer supported after a reevaluation of the system head loss was conducted using more conservative inputs and methodologies.

The NRC staff discussed the remaining margin with the licensee during a public meeting and the licensee noted that significant margin still exists in the head loss evaluation. The NRC staff finds the response to RAI 18 acceptable because the overall head loss value included CSHL. The NRC staff also notes that although 50 percent margin is no longer used by the licensee, that significant margin is still available in the strainer design.

In RAI 19, the NRC staff noted that the chemical effects head loss testing resulted in significant spikes in head loss immediately following the non-chemical debris additions. RAI 19(a) requested an explanation for this behavior and a justification that the spike in head loss would not occur in the plant. The licensee responded that the spike in differential pressure was not representative of a high head loss that could occur across the plant strainer but was a perturbation of the instrumentation caused by the rapid addition of debris. The response stated that debris in the plant would arrive much more gradually. The NRC staff concluded that the spike in head loss was not prototypical of plant strainer behavior based on the debris arrival times expected and the larger strainer area in the plant. The NRC staff also noted that similar spikes in head loss did not occur during the other testing performed by the licensee. Based on the NRC staff's knowledge of strainer behavior during a significant number of other industry tests and the earlier licensee testing, the NRC staff concluded that the head loss spikes were not prototypical of plant behavior. Therefore, the response to RAI 19(a) is acceptable.

In RAI 19(b), the NRC staff requested justification that the chemical constituents were added at a time such that a conservative chemical bump-up factor would be determined. The NRC staff concern was based on a decreasing head loss at the time that chemicals were added to the test. The licensee responded that the decrease in head loss was primarily due to fluid temperature increase and that the non-chemical debris bed had been established for about 24 hours prior to the addition of the chemicals. The licensee also stated that earlier non-chemical tests had exhibited similar behavior where the head loss tended to slowly decrease over time and concluded that the debris bed condition was appropriate at the time that chemicals were added to the test. Based on the fact that the debris bed had been formed 24 hours prior to the addition of chemicals and that the temperature increase was the primary driver for the head loss decrease the NRC staff finds the response to RAI 19(b) acceptable.

In RAI 20, the NRC staff requested that the licensee provide the design maximum allowable and maximum postulated strainer head loss for the small break LOCA condition. Alternately, the RAI requested that the licensee otherwise justify adequate strainer operation under the small break LOCA condition. The licensee responded that the allowable head loss for the small break LOCA case is half of the strainer submergence of 4.8 ft (2.4 ft). The licensee further stated that the debris load for the small break LOCA (SBLOCA) is significantly less than the large break case and that the head loss for the large break was less than 2.4 ft. Therefore, additional evaluation of the SBLOCA case was not conducted. The NRC staff concluded that since the SBLOCA acceptance limit was bounded by the head loss determined for the LBLOCA cases and the SBLOCA debris loading would be smaller than the LBLOCA debris loading that additional evaluation of the SBLOCA case was not required. The response to RAI 20 is acceptable.

In RAI 21, the NRC staff requested justification that the flow rate used during the chemical effects testing was bounding with respect to the flow that could occur in the plant. The NRC staff was concerned that the flow rate used during chemical effects testing may have been non-conservatively low. The licensee responded that the flow rate used during the chemical effects testing assumed that 90 percent of the main strainer area was blocked and that the resulting flow rate was equivalent to about 67 percent of the total maximum flow rate.

The response stated that since chemical effects are not anticipated to occur until later in the event that the assumed flow rate should bound that expected at the main strainer when most of the debris had transported to the strainer. The licensee also noted that if 67 percent of the flow is through the main strainer, only 33 percent of the flow passes through the remote strainer, which is larger than the main strainer. The lower flow rate through the remote strainer would result in a significantly lower head loss. Based on the use of a relatively high flow rate though the main strainer, the licensee concluded that the bump-up factor determined by the testing was a reasonable maximum value. The NRC staff concluded that the flow rate used during the chemical effects testing was conservative and that the chemical effects testing resulted in a reasonable maximum value for chemical effects head losses. The conclusion was based on the flow rate being equal to about 2/3 of the total maximum possible flow through less than ½ of the total strainer area.

NRC Staff Conclusion

For the head loss and vortexing area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Because the analysis for CNP was more complex than for other plants the evaluation contained significant conservatism to offset uncertainty added by the methods. The information provided by the licensee provides adequate assurance that the strainer will perform its function during any required recirculation operation at CNP. Therefore, the NRC staff concludes that the head loss and vortexing evaluation for CNP 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 respective NPSH margins for the ECCS and CTS pumps that would exist during a LOCA, considering a spectrum of break sizes.

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through May 26, 2010.

The NPSH area was addressed by providing the information specified in the revised content guide. The initial supplemental response, dated February 29, 2008, indicated that the final strainer head loss testing results were not included and that the final supplemental response would include any changes identified in the NPSH margin. In the response of August 29, 2008, the licensee stated that the information provided in the original response remained valid.

The methodology used is standard industry practice for calculation of NPSH margin and used a combination of realistic and conservative assumptions.

The CNP ECCS and CTS each include two trains of pumps. Each ECCS train consists of one high head centrifugal charging pump (CCP), one intermediate head safety injection (SI) pump, and one low head residual heat removal (RHR) system pump. Each CTS train has one pump. On actuation of the SI signal (start of the injection phase) the CCPs automatically realign suction from the volume control tank to the refueling water storage tank (RWST), the other ECCS pumps start with suction from the RWST, and the four SI accumulators discharge into their respective loop cold legs (if the break is large enough). A CTS actuation signal or manual actuation starts the CTS pumps that have suction aligned to the RWST.

The CTS pumps discharge to the spray headers. The ice condenser doors open and the non-condensable gases from the lower compartment and steam from the break pass up through the ice condensers starting the ice melt. The containment equalization system (CEQ) fans start circulating the non-condensable gasses from the upper containment compartment back to the lower containment compartment and thus back through the ice condensers.

When RWST level drops below 20 percent (in about 20 minutes for the large break design basis LOCA) and adequate containment pool water level is confirmed, operators enter the recirculation phase by manually switching the RHR and CTS pump suctions from the RWST to the containment recirculation strainers. When RWST level drops below 11 percent the SI and CCP suctions are shifted to the RHR pump discharge.

The supplemental response stated that the CNP-1 RHR pump flows are 4,093 gpm and 4,047 gpm for single pump operation, and the CNP-1 CTS pump flows are 3,251 gpm and 3,279 gpm. The CNP-2 RHR pump flows are 4,175 gpm and 4,173 gpm for single pump operation and the CNP-2 CTS pump flows are 3,253 gpm and 3,281 gpm. The UFSAR indicates that the maximum flow is 4,500 gpm for the RHR pumps and 3,300 gpm for the CTS pumps. The maximum assumed flow for dual RHR pumps operation is 3,800 gpm each. Therefore, a maximum/bounding recirculation sump flow of 14,400 gpm was used for the strainer head loss determination. The single operating RHR pump flows were used for determining the minimum NPSH for those pumps. The pump flow rates were determined using the Proto-Flo hydraulic analysis code.

The supplemental response identified the maximum sump water temperature as being 190 degrees Fahrenheit (°F) at the start of recirculation and decreasing rapidly from that value as ice condenser melt water continues to drain to the sump.

The supplemental response indicated that the NPSH analyses assumes a water level of about 4 feet above the containment floor inside the sump while the minimum containment water level for a LBLOCA is 5.9 ft and is 5.1 ft for a SBLOCA.

The submittal stated that the NPSH required values were based on the industry standard practice criterion of 3 percent loss of head. Containment accident pressure is assumed not to contribute to NPSH available. The NPSH is calculated assuming that containment pressure is -1.5 psig which is the lowest pressure allowed by technical specifications.

The supplemental response showed the following minimum pump NPSH margins. Maximum water temperature occurs at the start of recirculation and minimum water level occurs 9 to 10 hours after the accident:

CNP-1 RHR Pumps……West 10.7 feet	East 14.1 feet
CNP-1 CTS Pump……..West 13.8 feet	East 14.7 feet
CNP-2 RHR Pumps……West 9.2 feet	East 13.2 feet
CNP-2 CTS Pump……..West 14.2 feet	East 15.1 feet

The assumptions for minimum sump water level include:

- Ice melt minimized and delayed with TS lower limit in RWST temperature and lake/emergency service water system water temperature, maximum delay in CEQ fan start and earliest CTS actuation
- No contribution from spray additive tank

- No displacement of water by other than walls and major structural elements
- Minimum mass transfer from the RWST and SI accumulators
- Holdup in
    - Spray piping
    - Airborne spray
    - Film drainage on walls and heat sinks
    - Holdup on horizontal surfaces
    - Holdup in inactive volumes
    - Assumed 9,500 gallon holdup in the refueling cavity

The licensee stated that the water level was calculated for a spectrum of break sized from the double ended cold-leg break down to a ½ inch break. For all of the analyses, the variables were skewed to values that would minimize the mass of water available to the sump.

The supplemental response states that the limiting single failure of a single RHR pump (assumed condition for maximizing an individual RHR pump flow to show its minimum NPSH margin). The response also discusses the loss of an entire train of ECCS and CTS or one CEQ fan. These latter failures would tend to improve the NPSH margin for the operating pump above what is analyzed. The pumps all have significant margin for NPSH with the pumps running at the maximum flow rate calculated.

The NRC staff asked one RAI in the NPSH area. RAI 25 requested that the licensee justify the assumption that ½ of the RCS volume and the volume of the accumulators be credited as mass sources for the sump pool. The NRC staff could not conclude that these volumes should be credited for all breaks because a small-break LOCA could result in the accumulators remaining full for an extended period and the RCS maintaining more than ½ of its volume. The NRC staff also requested that the licensee evaluate whether the RCS would accommodate a larger mass of water as it cooled off due to increased water density. The NRC staff noted that non-conservatism in the water level calculation could affect the vortexing and air entrainment evaluation for the strainer and the NPSH margin calculation.

The licensee stated that the supplemental response discussion questioned by the NRC staff was strictly regarding large breaks. The licensee provided additional discussion about small-break LOCAs and stated that the Modular Accident Analysis Program (MAAP4) code was used to calculate post-accident behavior, including the containment building water level. The licensee stated that a failure modes and effects analysis was performed to identify key parameters to determine whether a sufficient amount of water would be available in the containment sump to support recirculation. Key parameters were adjusted to minimize the amount of water reaching the sump or reduce the rate of water addition to the sump. The licensee stated that the analyzed 2-inch SBLOCA minimum level would bound or be similar to the minimum water level for breaks on larger lines at the top of the pressurizer. The licensee's response also pointed out that the quantities of debris that could be generated for small breaks are significantly less than the limiting debris generation break size case and it is likely that less debris would transport to the strainer. The licensee stated that no revision to the minimum water level calculation was necessary to address the RAI. Based on the information provided, the NRC staff considered that the licensee demonstrated that the NPSH minimum water level calculation was conservative for all breaks. Furthermore, the licensee also showed that the quantity of problematic debris that could be generated from breaks on the top of the pressurizer would be substantially less than the limiting breaks. Therefore, the NRC staff agreed that the licensee has shown that the breaks located on the top of the pressurizer are bounded by the existing analysis.

NRC Staff Conclusion

For the NPSH area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the NPSH evaluation for CNP is acceptable. The NRC staff considers this area closed for GL 2004-02.

10.0 COATINGS EVALUATION

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

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through May 26, 2010.

The ZOI used for qualified coating systems was 5D which is acceptable by WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings" (ML061990594; not publicly available, proprietary information), since the qualified systems are either epoxy or top coated with epoxy. All qualified coatings in the ZOI fail as fine particulate.

One hundred (100) percent of the unqualified coatings are assumed to fail. The licensee categorizes the unqualified coatings into original equipment manufacturer (OEM) OEM-epoxies, OEM-alkyds, non-OEM-epoxies, and non-OEM-alkyds. The OEM-epoxies and OEM-alkyds fail as fine particulate which is acceptable to the NRC staff. The non-OEM-epoxies and –alkyds fail as chips of sizes 200-4,000 microns based on the Keeler and Long Report. This is not acceptable to the NRC staff. The Keeler and Long report is only applicable to degraded qualified coating epoxies. Therefore, the alkyds and unqualified epoxies must be assumed to fail as fine particulate, unless the licensee has additional test data.

During strainer testing CNP did not observe a thin bed when only fiber was included in the test but has enough Cal-Sil in the plant to create a thin bed. From the review guidance, if there is a thin bed present, all coating debris should be treated as particulate and transport to the sump. CNP used "engineering judgment" to determine the size distribution of the coating debris (page 243 of the initial supplemental response) (ML080770396). Although only a small fraction of chips was approximated, the justification of the use of chips was not justified.

In the pool, there is settling of the particulate which was determined by Stokes Law (and CFD). This issue is evaluated in the transport section.

The stone flour surrogate used for coatings particulate is acceptable to the NRC staff. The paint chip surrogate was not described and therefore, the NRC staff requested additional information regarding the surrogate chips.

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

In the August 29, 2008, submittal, CNP referenced a Keeler & Long report dated April 24, 2008, to justify a reduction in the amount of cold galvanizing compound that would fail. This reduction in quantity did not affect the inputs for head loss testing but was used as an input for the downstream effects wear evaluation. Since this new information did not impact head loss, a review in this section was not necessary.

In RAI 22, the NRC staff requested additional information for the use of Keeler and Long Report No. 060413 to justify the failure of non-original equipment manufacturer alkyds and epoxies as chips. The NRC staff noted that the Keeler and Long report is only applicable to degraded qualified epoxies and not unqualified epoxies or alkyds. The licensee provided information that confirmed that the non-OEM epoxies were equivalent to those in the Keeler and Long report. In addition, the licensee stated that the non-OEM alkyd coatings were observed to fail as chips, and that these coatings represent less than 0.4 percent of the coating total debris used in testing. The NRC staff does not accept that the alkyds will fail as chips but recognizes that their contribution to the total debris load is insignificant and that the debris amounts were calculated conservatively. The NRC staff has evaluated the response to RAI 22 and found it to be acceptable.

In RAI 23, the NRC staff requested that the licensee provide additional information regarding the characteristics of the paint chip surrogate used in testing, including the density and type of paint used. In addition, the NRC staff asked for clarification of how the paint chip surrogate is similar to the expected coating debris. The licensee responded that the surrogate epoxy was Carboline 890 with a density of 98 pounds per cubic foot (lb./ft^3), and the surrogate alkyd was Rustoleum with an approximate density of 70 - 80 lb./ft^3. This answers the NRC staff's concern and is acceptable to the NRC staff because of similarity to coating systems used in the plant. Regarding the similarity between the plant coatings and surrogates, the licensee responded that the majority of chips used in testing were smaller than the strainer opening since using the larger chip sizes from the Keeler and Long report would not lead to transport. In addition, less than 0.8 percent of the coating debris used in testing was in the form of these chips. The NRC staff has reviewed the response and found it to be acceptable since using the smaller chips led to more debris inclusion in the testing. In addition, the licensee could have justified that the majority of chips would not transport to the strainer due to low strainer approach velocity (NUREG/CR-6916, "Hydraulic Transport of Coating Debris" dated December 2006 (ML070220061)) and would not have to be included in testing.

<u>NRC Staff Conclusion</u>

For this review area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the coatings evaluation for CNP is acceptable. The NRC staff considers this area 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 CTS recirculation functions.

NRC Staff Review

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

The licensee provided a description of the programmatic measures that will ensure that potential sources of debris introduced into containment will be controlled. The licensee provided a list of the containment housekeeping programmatic controls in place to reduce latent debris amounts. Since CNP is treated as an RMI/low-fiber plant, the licensee provided a description of the programmatic controls to maintain the latent debris fiber source term in the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid.

The licensee discussed the foreign material exclusion program which controls the introduction of foreign material into the containment. The licensee also described how permanent plant changes inside containment are programmatically controlled to maintain the analytical assumptions and inputs used in their analyses.

The licensee briefly discussed how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65. It also described recent insulation replacements which will reduce the debris load at the sump strainers. The licensee also described actions taken to modify existing insulation to reduce the debris burden at the sump strainers.

The licensee has procedures and processes to assure containment cleanliness is maintained at a level that will ensure the latent debris burden inside containment remains at or below the total quantity assumed in the recirculation sump strainer analyses. The necessary housekeeping requirements are a part of the work package and pre-job brief for each work activity inside containment. The licensee has a housekeeping procedure in place.

During outage periods, periodic assessments of the status of containment cleanliness conditions are performed -and reported to station management. Prior to the end of the scheduled outage, an extensive containment cleaning effort is undertaken including vacuuming of accessible surfaces. Following cleaning in an area of containment, multiple walk downs are performed by members of station management, members of the Performance Assurance organization, and by Operations personnel as part of their containment close-out inspection.

The licensee stated that it will perform sampling of latent debris in containment when major work activities that could result in the generation of significant quantities of latent debris are performed, e.g., steam generator replacement.

The licensee has established extensive and comprehensive programmatic and process controls to limit the introduction of debris sources into containment during outage periods and during containment entries.

These controls include both engineering requirements for changes to the plant and process controls to ensure materials taken into containment are limited and controlled to ensure the inputs and assumptions that support overall resolution of GL 2004-02 will be maintained.

The licensee removed the Cal-Sil insulation from the pressurizer relief tank and pressurizer safety and relief valve discharge line below the pressurizer floor in both CNP-1 and CNP-2 (approximately 210 ft^3 in each unit). In CNP-1, LDFG insulation on the combined non--RCS systems relief valve discharge line to the PRT was removed (approximately 4 ft^3). In CNP-2, the Cal-Sil insulation on the pressurizer relief tank drain line was removed (approximately 10 ft^3). These last two insulation sources did not exist in the opposite unit.

The licensee removed a significant quantity of labels from containment. The licensee also removed areas of leveling compound from the floor in the loop compartment in both units' containments. This compound would have contributed a significant quantity of unqualified coatings to the overall debris source term.

NRC Staff Conclusion

For this review area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the debris source term evaluation for CNP 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 review the basic description of and information provided for the sump screen modification.

NRC Staff Review

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

The licensee provided a detailed description, along with pictures and drawings of the sump screen modification. It also identified the modifications, such as rerouting of piping, relocation of supports and other components, and the addition of whip restraints and missile shields, necessitated by the sump strainer modifications.

The licensee replaced the existing trash racks and screens with CCI pocket-style strainers that integrate the trash rack and screen functions while significantly increasing the overall strainer surface area. The licensee also increased the strainer area by installing a remote strainer in the annulus outside the RCS loop compartment. The remote strainer is connected to the recirculation sump via a sealed waterway that penetrates the divider wall in the recirculation sump. The divider wall is an extension of the containment crane wall. The total recirculation sump strainer area was increased from 85 ft^2 to 1,972 ft^2. The main strainer has an effective strainer area of 900 ft^2 and the remote strainer has an effective area of 1,072 ft^2. The screen/strainer openings were reduced from nominal 1/4-inch square openings to nominal 2.1 millimeters (mm) (- 1/12 in.) circular openings. The strainers are constructed primarily of stainless steel. The minimum submergence of the strainers at the minimum water level for a LBLOCA is greater than 6 in.

The licensee modified the recirculation sump vents to ensure the vent functions would not be inhibited by accident generated debris, and to ensure that debris larger than the recirculation sump strainer openings would not bypass the strainers. New level instruments were added inside the recirculation sump enclosures to provide indication and alarm in the control room. During the recirculation phase of ECCS operation, these instruments are designed to alert the operators to a condition in which head loss across the strainers had caused the water level inside the sump to decrease to the extent that vortex formation may occur.

The licensee installed debris interceptors over the drains from the CEQ fan rooms to ensure drainage of spray water from the upper compartment of containment to the lower containment sump pool. Debris interceptors were installed in other locations to prevent debris build up and blockage of drainage paths to the sump. Debris interceptors were also installed around the openings of the containment wide range level instruments stilling wells to reduce the potential for debris to block their inlet openings. A debris gate was installed in the annulus area outside the crane wall to guard against the transport of debris to the remote strainer.

The licensee modified the openings on the five existing 10-inch diameter openings that exist in the flood-up overflow wall by flaring the edges of the holes to reduce head loss across the openings. Additionally, the radiation shields that are installed on the annulus side of the openings were modified by removing approximately 2 inches from the bottom of the shields to prevent debris from building up between the shields and the flow openings, potentially impacting flow through these openings.

The licensee installed a blank plate in the crossover pipe that connects the lower containment sump to the recirculation sump. These sumps are adjacent to each other inside the crane wall. Previously, the connecting pipe had a nominal 3/16-inch mesh screen installed to limit the size of debris that could be transported from the lower containment sump to the recirculation sump. Installation of the blank plate will prevent any debris from bypassing the recirculation sump strainers through the crossover pipe.

NRC Staff Conclusion

For the screen modification package review area, the licensee provided screen location, configuration, and construction 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 CNP is acceptable. The NRC staff considers this item closed for GL 2004-02.

13.0 SUMP STRUCTURAL ANALYSIS

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

NRC Staff Review

The NRC staff's review is based on section 3k, Sump Structural Analysis, of the licensee's February 29, 2008, submittal.

The NRC staff review of section 3k has led to the conclusion that the licensee has adequately addressed the information requested by the Revised Content Guide for GL 2004-02 Item 2(d)(vii). The licensee's submittal stated that the maximum stress induced in the components associated with the replacement sump strainer modules were shown to be within the allowable stress limits of the design code of record, the American Institute of Steel Construction (AISC), 7th Edition.

The licensee's submittal stated that a series of finite element analyses (employing ANSYS and SAP computer software) and static calculations were performed to structurally qualify the replacement sump strainer modules. These calculations encompass the waterways and the main and remote strainers for both operating units. The structural models were subjected to bounding loading combinations consisting of dead weight, debris weight, hydrostatic loads, hydrodynamic loads, design basis earthquake loads, and thermal effects at various operating temperatures of the system. These considerations are all consistent with the NRC staff approved guidance of NEI 04-07. The maximum induced stresses for each component were then evaluated against the applicable allowable stress value from the licensee's design code of record. Although several of the interaction ratios were near the limit (0.99 < 1.0), the tabulated components were shown to ultimately be within the allowable stress limits.

In order to address the potential of dynamic effects on the strainer modules due to an HELB, the licensee stated that the RCS loop piping is not a credible high-energy source due to the adoption of leak before break analysis. Furthermore, the submittal stated that the remaining high-energy sources were all at a distance in excess of 10-pipe diameters from the strainer modules. This separation distance has been accepted by the NRC staff to conclude that no structural damage will occur to a potential target. Lastly, the licensee stated that their current design criteria preclude all systems, structures, and components within containment from failures which generate potential missiles that could impact required safety-related equipment. For this reason, potential missile impact loads were also not considered.

The licensee's submittal stated that back flushing was not credited as a mitigating strategy for the replacement sump strainers. However, reverse flow through a strainer was considered within the loading condition specified as "Pool Fill Hydraulic Loads".

The information provided by the licensee shows that the sump structural evaluation contains inherent conservatism by complying with the design code of record (AISC, 7th Edition). All interaction ratios were stated to be within the allowable limits with the maximum value of more than one component being 0.99. There are several variables and assumptions which can influence the outcome of dynamic and static analyses such as were performed for the replacement strainer modules. For this reason, the NRC staff cannot conclude the overall significance of the conservatism. The licensee has provided sufficient information, however, to show that a level of conservatism exists and the intent of the Revised Content Guide for GL 2004-02, Item 2(d) (vii), has been met.

The NRC staff review of the information provided by the licensee contains those basic elements which were requested by the Revised Content Guide. For this reason, the NRC staff finds that the information provided by the licensee did not contain any significant gaps that could impact the conclusions of the sump structural analysis.

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

NRC Staff Conclusion

For this review area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the sump structural analysis evaluation for CNP 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 on documentation provided by the licensee through August 29, 2008.

The licensee evaluated the flowpaths upstream of the containment sump for holdup of inventory which could reduce flow to or hold up inventory from reaching the sump. The licensee provided the basis for concluding that the water inventory required to ensure adequate ECCS or CTS recirculation would not be held up or diverted by debris blockage at chokepoints in containment recirculation sump return flowpaths. The evaluation considered the flow paths in the containment sump inventory analysis including flow paths associated with the strainers both inside and outside the crane wall. The debris transport analysis also performed an evaluation of the potential choke points in the recirculation transport paths. The information provided identifies potential choke points in the flow field upstream of the sump and summarizes measures taken to mitigate potential choke points. The evaluation of water holdup at curbs and/or debris interceptors was summarized. A summary of the evaluation of the potential blockage of reactor cavity and refueling cavity drains was also provided.

An evaluation was made of the potential holdup of water in the refueling cavity. This evaluation conservatively determined that approximately 9,500 gallons of water would be held up in the refueling cavity. The licensee also calculated that approximately 117,795 gallons of water would be held up in the reactor cavity.

The licensee stated that the 7-inch curb at the entrance to the recirculation sump was removed. The new main strainer support base creates an approximate 4 in curb. The licensee stated that the 12-inch curb on the annulus side of the flood-up overflow wall openings would have a negligible effect because CNP's minimum water level is substantially above the elevations of these curbs.

NRC Staff Conclusion

For this review area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the upstream effects evaluation for CNP 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 (ex-vessel) section is to evaluate the effects of debris carried downstream of the containment sump screen on the function of the ECCS and CTS 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 August 29, 2008.

The licensee provided a detailed description of the ex-vessel downstream evaluations performed to address the issues identified in GL 2004-02. The licensee stated that it has completed an analysis of ex-vessel wear, abrasion, erosion, and pump blockage using the guidance of WCAP-16406-P-A, Rev. 1 and the associated NRC SE. The results of the evaluation determined that the RHR, CTS, and centrifugal charging (CC) systems will successfully operate for a minimum 30-day mission time. Using the guidance of WCAP-16406-P-A, Revision 1, the licensee determined that after approximately 15 days of operation with debris-laden fluid, the SI pumps could experience excessive vibration. The licensee stated that the required mission time for the SI pumps after a LOCA is a maximum of 30 hours. Therefore, to protect the SI pumps and maintain them available for future use, if needed, the licensee revised procedures to clarify existing guidance regarding removal of unnecessary equipment from service.

The evaluation was a bounding evaluation for both units using a detailed methodology to evaluate systems, components, and instrumentation that could be affected by debris that could pass through the recirculation sump strainers. The licensee reviewed the recirculation flow path alignments to ensure that all required flow paths and components impacted by debris passing through the strainers were evaluated. The evaluation compared the size of the limiting flow passageways to the size of the debris that could pass through an assumed 1/8-inch (0.125 inch) strainer opening. This assumed strainer opening bounds the nominal opening size in the CNP strainers of 1/12 inch (0.083 inch) and bounds the maximum opening size of 3/32 inch (0.094 inch) at the dimple areas in the strainer pockets. A determination of the expected velocity in the various ex-vessel flow paths was also performed to ensure that sufficient velocity existed to prevent debris settling and accumulating in the lines. The licensee provided the following information regarding the wear evaluation:

- The pump wear evaluations considered both abrasive (free flow and packing) and erosive wear as described in WCAP-16406-P-A. The pump wear evaluations also considered both hydraulic effects and mechanical effects as a result of the wear evaluations. A significant conservatism added to the pump wear evaluation was that the pumps were considered to be at their minimum operability limit for hydraulic verification at the start of recirculation. In-service testing results were used to predict wear to the end of plant life, then added the determined wear due to pumping debris-laden water for the pump mission time for mechanical verification.

- The evaluation determined that the CC, RHR, and CTS pumps would function satisfactorily for the required 30-day mission time. The SI pumps were determined to be able to function satisfactorily, at their design flow rate, for a maximum of 15.4 days.

Based on the plant accident analysis requirements, the SI pumps are conservatively determined to be required for only the first 30 hours following a LOCA.

- The wear evaluation for other ex-vessel components determined that the installed throttle valves, heat exchangers, spray nozzles, and some of the installed orifices would have debris induced wear less than allowed by the guidance given in the WCAP. Some of the orifices installed in the systems were determined to wear in excess of the guidance. To ensure that the necessary core and containment flow would be maintained after subjecting the pumps to the wear evaluations, pump curves were generated for each of the CNP pumps. Additionally, to ensure pumps would not reach run-out conditions, an analysis was performed of the systems that included the predicted wear of components within the flow paths integrated with the pump curves that were generated. The results of this analysis determined that the necessary core and containment cooling would be maintained and that none of the pumps would reach a run-out condition based on system wear. The pump seals were also evaluated for the potential for failure due to pump operation with debris-laden fluid. The evaluation determined that the seals would not fail.

NRC Staff Conclusion

For this review area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the licensee's evaluation of this area for CNP 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 LTCC.

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through May 26, 2010.

The licensee stated that an analysis of the in-vessel blockage, localized debris buildup, and plate-out was performed in accordance with WCAP-16793 using the LOCA Deposition Model (LOCADM) analysis methodology with consideration of the NRC's draft SE on that document. The licensee considers the evaluation as a LOCADM evaluation. The licensee also performed an evaluation of the potential for fuel assembly bottom nozzle inlet blockage from fibrous debris. For the minimum sump water volume cases, LOCADM was also run with increased quantities of debris in accordance with the "bump-up factor" methodology recommended by the PWROG. The licensee stated that the "bump-up factor" had a negligible effect on both the total deposition thickness and fuel cladding temperature.

In its initial response, the licensee stated that the results of the fuel assembly bottom nozzle blockage evaluation determined that the fiber bed formed would be approximately 0.028 in. thick, significantly less than the value assumed for formation of a thin bed, 0.125 in. It should also be noted that the openings in the fuel assembly bottom nozzles for CNP are 5.66 mm (0.221 in.) for CNP-1, and 4.83 mm (0.190 in.) for CNP-2. The smallest of these openings, 4.83 mm is twice the size of the maximum recirculation sump strainer opening of 2.4 mm.

To determine the quantity of fiber that would pass through the strainer, a test was performed at CCI. The test was performed in the MFTL using a strainer module that represented the main strainer only. The flow rate used for the test represented a plant flow rate of 9,720 gpm. This value represents the flow rate through the main strainer with this strainer 90 percent blocked (1.0 percent open area). The quantity of fiber that was determined to pass through the strainer was 1.16 percent. In addition to the latent debris fiber that is conservatively assumed to be resident in the plant containments, the fiber contribution from Cal-Sil, Marinite, and Min-K was also included in the total fiber passing through the strainer. The total volume of fiber from all sources, available for capture by the fuel assembly bottom nozzles, was determined to be 0.228 ft^3. This value considers the total quantity of fibers from all sources in containment that could pass through the main and remote strainers, as a function of the debris transport fractions and the bypass testing that was performed. Based on the information provided above, it is reasonable to conclude that significant blockage of the fuel assembly bottom nozzles will not occur due to the size of the openings in relation to the size of the debris that can pass through the strainers. Additionally, the deposition model demonstrates that the deposits on the fuel cladding will not result in unacceptable fuel clad temperatures or fuel clad deposition thickness.

In its response dated May 26, 2010, the licensee provided updated information including the calculated debris load per fuel assembly using different assumptions. One calculation was performed for a 1.2 percent bypass fraction and one was performed for a 5 percent bypass fraction. The licensee also assumed a conservative latent fiber source term of 30 lb. The licensee stated that each unit has 193 fuel assemblies. The licensee calculations how that using the 5 percent bypass fraction and a 30 lb. source term for fiber, that the debris loading per fuel assembly is about 3.5 grams.

The licensee previously completed a plant-specific strainer bypass test as documented in its August 29, 2008, response. Due to questions regarding the reliability of the testing method, discussed above, the licensee elected not to use the test results. The licensee applied the NEI clean plant criteria (i.e., 45 percent fiber penetration (bypass) fraction and 75 percent debris transport fraction) to determine the amount of fibrous debris penetrating the sump strainers for use in the downstream in-vessel debris analysis for CNP. The clean plant criteria, as accepted by the NRC (ML120730181) states that the licensee should demonstrate that the 45 percent penetration and the 75 percent transport values are applicable to the plant specific conditions. The licensee did not directly address these parameters. However, the NRC staff considers the 45 percent value an upper limit for strainer penetration for plants with typical fibrous debris and strainer approach velocities, even for plants with very low fiber loading. Therefore, the NRC staff finds the 45 percent penetration value acceptable. The NRC staff also finds that the 75 percent transport value would be realistic to conservative for an ice containment because some fine debris will be captured in inactive volumes and would be inertially captured on surfaces. In addition, the NRC staff noted that the licensee made conservative assumptions in its debris generation evaluation. Both the amount of latent debris and Temp-Mat were significantly overestimated compared to realistic values. The conservatism in debris generation does not directly address the guidance, but it shows that there is additional margin.

The licensee conservatively assumed the mass of latent fibrous debris as 30 pounds-mass (lbm) and stated that a plant-specific value of 12 lbm was a bounding value determined by walkdowns. The worst-case amount of fibrous debris generated is 7.6 ft^3 of Temp-mat. The density of Temp-mat is 11.8 lbm/ft^3 which results in a worst-case generation of approximately 90 lbm. Therefore, the total mass of fibrous debris is 120 lbm.

Based on this, the in-vessel fiber load is 95 grams per fuel assembly (g/FA), was be compared to the applicable WCAP-17788-P, "Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090)," Revision 1 (Package ML20010F181) in-vessel debris acceptance criterion.

CNP-1 and CNP-2 are Westinghouse 4-loop PWRs with a converted upflow barrel/baffle configuration. CNP-1 uses Westinghouse 15x15 Upgrade Fuel Assembly and CNP-2 uses Westinghouse 17x17 Optimized Fuel Assembly.

The licensee stated that the proprietary total in-vessel fibrous debris limit in section 6.5 of WCAP-17788-P, Volume 1, Revision 1, applies to CNP. The licensee stated that the maximum amount of fiber calculated to potentially reach the reactor vessel (95 g/FA) is less than the WCAP acceptance criterion for total in-vessel fiber.

The licensee stated that it assumes that all fibrous debris calculated to penetrate the strainer reaches the reactor vessel, which consists of latent debris and accident generated Temp-Mat debris.

The licensee stated that the applicable core inlet fiber threshold applicable to CNP is in Table 6-3 of WCAP-17788-P, Revision 1. The licensee stated that while the 95 g/FA exceeds the core inlet fiber limit, it is less than the total in-vessel debris limit. WCAP-17788-P as well as WCAP-16793 conservatively assumed uniform debris at the core inlet because it would result in the greatest head loss for a given amount of debris. However, the licensee stated that the debris bed is expected to collect non-uniformly, resulting in a greater amount of debris required to completely block the core inlet than that assumed in the analyses, as discussed in the technical evaluation report on IVDEs. Therefore, the licensee stated that the core inlet fiber limit is not a critical parameter and the current LTCC analyses remain applicable.

The licensee stated that if the core inlet did become completely blocked, alternate flow paths (AFPs) allow flow to reach the core. The licensee stated that the plant-specific calculated AFP resistance is similar to the generic resistances in WCAP-17788-P and, therefore, the plant-specific AFPs would be effective to maintain core cooling.

The assumption of non-uniform debris deposition at the core inlet and flow through the AFPs is consistent with NRC staff guidance (ML19228A011).

The licensee stated that the earliest possible sump switchover tie for CNP is 23.14 minutes.

The licensee compared its plant buffer, sump pool pH, volume and temperature, and debris types and quantities to Test Group 26 from Volume 5 of WCAP-17788-P, Revision 1. The licensee's description of key plant materials and projected post-LOCA environment was confirmed by the NRC staff to be represented by Test Group 26 from Volume 5 of WCAP-17788-P, Revision 1. The NRC staff also verified the WCAP test results representative of CNP have a predicted chemical precipitation timing (t_{chem}) of 24 hours.

The licensee stated it performs injection realignment to mitigate the potential for boric acid precipitation no later than 7.5 hours following an accident, which is less than 24 hours. The licensee stated that based on Table 6-1 of Volume 1 of WCAP-17788-P, Revision 1, complete core inlet blockage timing (t_{block}) for CNP is 143 minutes. The licensee confirmed that the t_{chem} of 24 hours is greater than the applicable t_{block} of 143 minutes.

The licensee stated that CNP-1 and CNP-2 have rated thermal powers of 3,304 megawatts thermal (MWt) and 3,468 MWt, respectively. The licensee stated that the applicable analyzed thermal power provided in Table 6-1 of Volume 4 of WCAP-17788-P, Revision 1, is 3,658 MWt. Because the plants' rated thermal powers are less than the analyzed power, this parameter is bounded by the WCAP AFP analysis.

The licensee stated that the proprietary plant-specific AFP resistance provided in Table RAI-4.2-24 of Volume 4 of WCAP-17788-P, Revision 1, reflects the plants in a downflow plant configuration. CNP-1 and CNP-2 are converted upflow barrel/baffle plants. Therefore, the licensee calculated a plant-specific AFP resistance for the barrel/baffle region. The plant-specific AFP resistance is a similar magnitude as other Westinghouse 4-loop converted upflow plants provided in Table RAI-4.2-24 and is, 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 from 8-40 gpm/FA, as shown in table 6-1 of Volume 4 of WCAP-17788-P, Revision 1. The minimum and maximum plant-specific ECCS recirculation flow rates are 15.5 gpm/FA and 39.4 gpm/FA, respectively. These flow rates are within the range of ECCS recirculation flow rates considered in the AFP analysis.

The licensee provided a comparison of key parameters used in the WCAP-17788 AFP analysis to the plant-specific values. Based on these comparisons, the licensee concluded that the CNP-1 and CNP-2 are bounded by the key parameters and the WCAP methods and results are applicable.

NRC Staff Conclusions

For this review area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was appropriately addressed. Therefore, the NRC staff concludes that the licensee's evaluation of this area for CNP 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 strainer head loss and core cooling.

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through May 26, 2010.

The licensee evaluated chemical effects head loss using several test methods. The testing included non-chemical debris tests in a large-scale tank (CCI), testing in the multifunctional test loops with non-chemical debris and a chemical injection technique (CCI) to establish a bump-up factor for large test, and 30 day Integrated chemical effects testing (Alion VUEZ large tank). The VUEZ testing conducted at the facility in Slovakia was not relied upon to develop the bump-up factor but provided additional data to show conservatism in the bump-up factor developed in CCI tank.

The initial supplemental response provided information on testing performed under the CCI "chemical injection" test procedure in the multifunctional test loop. It also reported the results of the large-scale tank testing with non-chemical debris only. The final report included the results the 30-day integrated testing performed in the large VUEZ test tank.

Chemical precipitate loading for the multifunctional test loop was determined based on WCAP-16530-NP. No refinements for solubility or inhibition were credited in the licensee's analysis.

The licensee stated that the aluminum amounts in containment are as follows:

- submerged = 10.93 ft^2
- non-submerged = 8,013.39 ft^2

The licensee stated that the mass of chemicals predicted by WCAP-16530-NP are as follows:

Case #1 (DEGB)
Sodium Aluminum Silicate ($NaAlSi_3O_8$) = 202,070 g
Aluminum Oxide Hydroxide (AlOOH) = 86,701 g
Calcium Phosphate ($Ca_3(PO_4)_2$) = 0 g
Total Predicted Precipitate Load = 288,771 g = 288.8 kg

Case #2 (DGBS)
$NaAlSi_3O_8$ = 67,802 g
AlOOH = 117,371 g
$Ca_3(PO_4)_2$ = 0 g
Total Predicted Precipitate Load = 185,173 g = 185.2 kg

The licensee stated that 100 percent of the aluminum and silicon that were injected into the multifunctional loop precipitated out based on chemical analysis of the test loop water. The licensee also stated that a significant amount of chemical precipitate formed in the loop based on visual observations. Pictures provided in the submittal show many of the strainer pockets almost entirely filled with white material that is consistent with the appearance of chemical precipitates observed by the NRC staff in other testing.

The multifunctional testing included chemical injections in increments up to 140 percent of the predicted WCAP values for dissolved aluminum, silicon, and calcium.

Settling values for the precipitates were determined based on bench tests using the same chemical introduction sequence as the multifunctional test loop. The bench test showed 88 percent of the fluid remained cloudy after 1 hour, based on the 100 milliliters (mL) graduated cylinder separation line between the cloudy precipitate and the clear fluid occurring at 88 mL. Although the CCI tests used a precipitate preparation method different from WCAP-16530, the NRC staff notes the one-hour precipitate settlement results would be acceptable using the WCAP-16530 criterion. The licensee stated that very little debris was observed to settle away from the strainer during testing in the multifunctional test loop.

The multifunctional test was run for 4 days after the final chemical addition. The termination criterion was less than 1 percent change in head loss over a 30-minute period for 2 consecutive 30-minute periods.

The licensee applied a bump-up factor of 1.7 to the large-scale test results based on the multifunctional test loop results. The actual bump-up value established by the CCI multifunctional loop tests was 1.53. The VUEZ data indicated a bump-up value of 1.4. The licensee cited the VUEZ testing as an indication of margin. The NRC staff agrees that the licensee has added conservatism to their chemical bump-up factor, however the NRC staff's assertion is not relying on the VUEZ testing. The NRC staff has previously identified significant issues with the test practices used at VUEZ on a different test facility where testing was being conducted for other licensees. Because CNP does not credit the VUEZ testing as part of its final solution, the NRC staff did not perform a detailed review of the test report. Therefore, the licensee should not attempt to credit the VUEZ data unless the technical issues associated with the VUEZ testing are addressed.

The VUEZ data provided by CNP does have some useful information including the potential impact of organics and other materials not considered in the CCI chemical effects head loss testing or in testing by other strainer test vendors. As stated above the NRC staff does not accept the VUEZ test, by itself, as an acceptable method to establish a chemical effects bump-up factor. But the licensee has demonstrated a questioning attitude and has applied multiple test methods to examine different phenomena. The result is a more complete analysis of potential scenarios than has been displayed by many other licensees.

The licensee stated that the single largest contributor to aluminum in the spray zone was the RCP motor cooling fins. These coolers are oriented with the faces vertical and the top of the cooler sealed such that spray could only enter through the face. The tubes are recessed 1 inch from the cooler face. The coolers are located approximately 20 ft. below the spray nozzles, and the spray would be predominantly vertical at that point. The licensee estimates that at least 30 percent of the fins would be completely unaffected by the spray. This would result in a reduction of dissolved Al in the sump. The licensee assumes 100 percent interaction of the spray with the fins. The pH and temperature inputs were conservatively chosen to maximize material dissolution.

CNP has both sodium tetraborate and sodium hydroxide to adjust sump pool pH following a LOCA. Table 3.o1-1 of the initial GL 2004-02 supplemental response (ML080770396) lists the chemical additions to the multifunctional test loop. This table includes sodium tetraborate but not sodium hydroxide. No justification was provided for excluding sodium hydroxide from the test.

Test data for the multifunctional test loop is provided in tables 3.o1-3 and 3.o1-4 of the initial supplemental response. When the non-chemical debris is introduced the head loss jumps considerably for the two cases tested (100 millibar (mbar) increase and 66 mbar increase). In both cases the head loss then decreases over several hours with no changes to flow rate, no other debris additions, and minimal changes in temperature (≈110 mbar drop and ≈118 mbar drop). This phenomenon was evaluated in the head loss section above.

The NRC asked several RAIs regarding chemical effects. In RAI 26, the NRC staff questioned the licensee's choice to use only sodium tetraborate in its head loss testing when the plant has sodium tetraborate in the ice and sodium hydroxide is added via containment spray. The licensee stated that the plant-specific pH was calculated using assumptions that resulted in a conservative amount of dissolved aluminum being calculated for inclusion in the head loss testing. In addition, the licensee stated that the test used sodium tetraborate, sodium aluminate, and boric acid to simulate the post-LOCA environment. The licensee stated that the addition of sodium hydroxide was not necessary to obtain satisfactory test results.

Since the licensee's response demonstrated a conservative approach to determine the chemical source term and since the CNP test parameters maintained the appropriate pH and boron levels, the NRC staff finds the licensee response to RAI 26 acceptable.

In RAI 27, the NRC staff requested that the licensee explain why late additions of chemicals to the head loss test did not impact the measured head loss. Since the late chemical additions were intended to provide conservatism by including chemical amounts beyond those calculated for the design basis case. The NRC staff requested that the licensee describe the actions taken to verify that the later additions of chemicals actually formed the intended precipitates since the head loss did not indicate that precipitation was occurring. The licensee stated that the head loss plots for the chemical effects tests showed significant increases in head loss up to and including the chemical additions that represented 100 percent of the design loading. This indicated that there was a significant chemical response for all precipitates that were conservatively predicted to be formed following the LOCA. The licensee also responded that chemical analysis indicated that additional precipitate was formed during the addition of chemicals beyond the design basis case but that due to bed morphology, these additions did not cause any additional significant increase in head loss.

This question was related to the extent of conservatism added by chemical additions beyond the amount intended to precipitate the design basis amount of precipitate. The licensee's analysis indicated that additional precipitate formed but debris bed characteristics resulted in a lack of head loss response. The NRC staff has observed similar behavior during other integrated chemical effect tests where debris bed shifting, bore holes, or other debris bed phenomena limit the pressure drop. The licensee's response is acceptable since their overall chemical effects approach was conservative and the test showed a significant head loss response to up to 100 percent of the predicted chemical addition amount.

The NRC staff requested additional information regarding several aspects of additional chemical effects testing performed at VUEZ in the large loop. The licensee stated that the results of the VUEZ testing were not being credited in its evaluation. Therefore, responses to the NRC requests are not required. RAIs 28 through 35 do not require responses.

<u>NRC Staff Conclusion</u>

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has been adequately addressed. The licensee has provided information such that the NRC staff has high confidence in the licensee's test and evaluation methods in this subject area.

The licensee performed containment emergency sump strainer testing and simulated chemical effects by adding particulates, chemical debris, and the appropriate fiber quantity. During chemical effects testing, the licensee generated precipitates in-situ in a quantity greater than the amount predicted by the use of the WCAP-16530-NP methodology. The licensee also used a chemical effects head loss multiplier greater than what was observed in the testing for additional margin. This is acceptable to the NRC staff since the licensee's overall prediction of chemical precipitates, the quantity added to the test loop, and the head loss incurred by chemical precipitates are treated in a conservative manner. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02.

18.0 LICENSING BASIS

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

Technical Specifications Task Force (TSTF) Traveler TSTF-567, Revision 1, “Add Containment Sump TS to Address GSI [Generic Safety Issue]-191 Issues,” (ML17214A813) was issued on dated August 2, 2017. The NRC issued a final SE approving TSTF-567, Revision 1, on July 3, 2018 (ML18116A606). The licensee committed to change the UFSAR in accordance with 10 CFR 50.71(e) to incorporate the GL 2004-02 response including the values of analyzed debris limits needed for TSTF-567 following receipt of NRC acceptance of this final supplemental response to the GL. On January 6, 2021, the NRC issued Amendment Nos 355 and 335 to CNP-1 and CNP-2, respectfully. The amendments revised the CNP technical specifications to adopt TSTF-567, Revision 1.

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 adequately addressed. Therefore, the NRC considers this item closed for GL 2004-02.

19.0 CONCLUSION

The NRC staff 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 CTS recirculation and, if necessary, take additional action to ensure system function in light of the potential for debris to adversely affect LTCC. The NRC staff finds that the information provided by the licensee demonstrates that debris will not inhibit the ECCS or CTS performance following a postulated LOCA. Therefore, the ability of the systems to perform their safety functions, to assure adequate LTCC following a DBA, as required by 10 CFR 50.46, has been demonstrated.

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

Principal Contributors: S. Smith, NRR
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Date: June 24, 2022

SUBJECT: DONALD C. COOK NUCLEAR PLANT, UNIT NOS. 1 AND 2 – CLOSEOUT OF GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (EPID L-2017-LRC-0000) DATED JUNE 24, 2022

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OFFICE	NRR/DORL/LPL3/PM	NRR/DORL/LPL3/LA	NRR/DSS/STSB/BC
NAME	SWall	SRohrer	VCusumano
DATE	06/14/2022	06/14/2022	06/14/2022
OFFICE	NRR/DNRL/NCSG/BC	NRR/DORL/LPL3/BC	NRR/DORL/LPL3/PM
NAME	SBloom	NSalgado	SWall
DATE	06/22/2022	06/24/2022	06/24/2022

OFFICIAL RECORD COPY