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

March 29, 2022

ANO Site Vice President
Arkansas Nuclear One
Entergy Operations, Inc.
N-TSB-58
1448 S.R. 333
Russellville, AR 72802

SUBJECT: ARKANSAS NUCLEAR ONE, UNITS 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 Sir or Madam:

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 16, 2013 (ADAMS Accession No. ML13137A126), Entergy Operations, Inc. (Entergy or the licensee) stated that it will pursue Option 2 (deterministic) for the closure of GSI-191 and GL 2004-02 for Arkansas Nuclear One, Units 1 and 2 (ANO).

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

Enclosed is the summary of the NRC staff's review. If you have any questions, please contact me at (301) 415-4037 or by e-mail at Thomas.Wengert@nrc.gov.

Sincerely,

/RA/

Thomas J. Wengert, Senior Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-313 and 50-368

Enclosure:
NRC Staff Review of GL 2004-02
for Arkansas Nuclear One, Units 1 and 2

cc: Listserv

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

U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW

OF THE DOCUMENTATION PROVIDED BY

ENTERGY OPERATIONS, INC.

FOR ARKANSAS NUCLEAR ONE, UNITS 1 AND 2

DOCKET NOS. 50-313 AND 50-368

CONCERNING RESOLUTION OF GENERIC LETTER 2004-02

POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING

DESIGN-BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

1.0 INTRODUCTION

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

If a LOCA occurs, piping thermal insulation and other materials may be dislodged by the two-phase coolant jet emanating from the broken RCS pipe. This debris may transport, via flows coming from the RCS break or from the containment spray system (CSS), to the pool of water that collects at the bottom of containment following a LOCA. Once transported to the sump pool, the debris could be drawn 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 CSS in recirculation mode at PWRs during LOCAs or other HELB accidents for which sump recirculation is required. The NRC completed its review of GSI-191 in 2002 and documented the results in a parametric study that concluded that sump clogging at PWRs was a credible concern.

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

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

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

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

By letter dated May 28, 2004 (ADAMS Accession No. ML041550661), the Nuclear Energy Institute (NEI) submitted NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology" (ADAMS Accession Nos. 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 (ADAMS Accession No. ML043280641), the NRC issued an evaluation of the NEI methodology. The NRC staff concluded that the methodology, as approved in accordance with the NRC staff safety evaluation (SE), provides an acceptable overall guidance methodology for the plant-specific evaluation of the ECCS or CSS sump performance following postulated 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" (ADAMS Accession Nos. ML050550138 and ML050550156), the Pressurized Water Reactor Owners Group (PWROG) sponsored the development of the following Westinghouse Commercial Atomic Power (WCAP) Topical Reports (TRs):

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

- TR-WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," dated March 2008 (ADAMS Accession No. ML081150379), to provide a consistent approach for plants to evaluate the chemical effects that may occur post-accident in containment sump fluids (NRC Final SE at ADAMS Accession No. ML073521072).

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

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

After the NRC staff evaluated licensee responses to GL 2004-02, the staff found that there was a misunderstanding between the industry and the NRC on the level of detail necessary to respond to GL 2004-02. The NRC staff, in concert with stakeholders, developed a content guide for responding to requests for additional information (RAIs) concerning GL 2004-02. By letter dated August 15, 2007 (ADAMS Accession No. ML071060091), the NRC issued the content guide describing the necessary information to be submitted to allow the NRC staff to verify that each licensee’s analyses, testing, and corrective actions associated with GL 2004-02 are adequate to demonstrate that the ECCS and CSS will perform their intended function following any DBA. By letter dated November 21, 2007 (ADAMS Accession No. ML073110389), the NRC issued a revised content guide (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 (ADAMS Accession No. ML121320270). The options are summarized as follows:

- Option 1 would require licensees to demonstrate compliance with 10 CFR 50.46, “Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," through approved models and test methods. 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 (ADAMS Accession No. ML12349A378), approving all three options for closure of GSI-191.

By letter dated May 16, 2013 (ADAMS Accession No. ML13137A126), Entergy Operations, Inc. (Entergy or the licensee) stated that it will pursue Option 2 (deterministic) for the closure of GSI-191 and GL 2004-02 for Arkansas Nuclear One, Units 1 and 2 (ANO-1 and ANO-2, respectively or ANO when referring to both units).

On July 23, 2019 (ADAMS Package Accession No. ML19203A303), GSI-191 was closed. It was determined that the technical issues identified in GSI-191 were now well understood and therefore, GSI-191 could be closed. Prior to and in support of closing the GSI, the NRR staff issued a technical evaluation report on in-vessel downstream effects (IVDEs) (ADAMS Accession Nos. 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" (ADAMS Accession No. ML19228A011).

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

GL 2004-02 CORRESPONDENCE		
DOCUMENT DATE	**ACCESSION NO.**	**DOCUMENT**
March 3, 2005	ML050740445	Initial Response to GL
June 2, 2005	ML051520286	1st NRC RAI
July 28, 2005	ML052200483	Licensee Response to RAI
August 31, 2005	ML052560230	Supplemental Information
December 15, 2005	ML053570248	Supplemental Information
February 9, 2006	ML060380575 (ANO-1) ML060380624 (ANO-2)	2nd NRC RAI
February 28, 2008	ML080710544	Licensee Response to RAI
September 15, 2008	ML082700499	Supplemental Information

GL 2004-02 CORRESPONDENCE		
May 21, 2009	ML091190322	3rd NRC RAI
September 24, 2009	ML092720684	Licensee Response to RAI
January 26, 2010	ML100190320	NRC Partial Closure Letter
April 8, 2010	ML100980614	Supplemental Information
September 29, 2010	ML102730943	Supplemental Information
December 21, 2011	ML120040124	Supplemental Information
May 16, 2013	ML13137A126	Closure Option
December 10, 2020	ML20353A115	Final Supplemental Response
July 16, 2021	ML21197A037	4th NRC RAI
October 4, 2021	ML21277A190	Licensee Response to RAI

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

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

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

- Replaced original strainers with an engineered modular design that has a filtering surface area of 2,715 square feet (ft^2) with 1/16” screen openings for ANO-1, and 4,837 ft^2 with 1/16” screen openings for ANO-2.
- Changed buffer from Tri-Sodium Phosphate (TSP) to Sodium Tetraborate (NaTB) (for ANO-2).
- Removed fibrous insulation and banded calcium-silicate (Cal-Sil) insulation.
- Performed latent debris sampling and characterization, including other debris sources, e.g., labels, etc.
- Generated and revised debris generation analyses based on walkdown information.
- Performed strainer head loss testing.
- Performed ex-vessel downstream effects analysis.
- Reduced post-accident buffer pH (for ANO-1).
- Performed NPSH analysis.
- Performed Cal-Sil erosion, transport, and dissolution testing (for ANO-2).
- Installed refueling canal drain strainers (for ANO-2).

- Established programmatic and procedural changes to maintain acceptable configuration and protect the newly established design and licensing basis (containment closeout, coatings, and housekeeping procedures; upper level document development).

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 September 15, 2008.

The licensee provided the information specified in the content guide, identified in Section 1.0 of this document.

The licensee described its use of the deterministic break selection methodology described in NEI 04-07 to identify the following postulated break locations. The ANO units are different designs, so the breaks evaluated for each unit are different. ANO-1 is a two-loop Babcock and Wilcox (B&W) design and ANO-2 is a two-loop Combustion Engineering (CE) design.

For ANO-1, the licensee evaluated the following break locations:

- S1 - 36 inch, Hot Leg, lower
- S2 - 8.75 inch, Pressurizer Surge Line
- S3 - 28 inch, Cold Leg, upper
- S4 - 36 inch Hot Leg, upper
- S5 - 28 inch, Cold Leg, lower
- S6 (Alt.) - 11.188 inch Alternate Break

For ANO-1 the postulated break locations listed were for the north cavity; comparable break locations were postulated in the south cavity, except S2 and S6.

For ANO-2, the licensee evaluated the following break locations:

- S1 - 42 inch, Hot Leg, A Steam Generator (SG), South
- S2 - 42 inch, Hot Leg, B SG, North
- S4 - 10.126 inch, Pressurizer Surge Line, South
- S6 - 30 inch, Cold Leg, A Reactor Coolant Pump, South

Secondary (main feedwater, main steam) piping breaks were not considered since the associated accident analyses do not credit CSS or ECCS recirculation.

The licensee did not indicate that RCS line breaks at the reactor vessel nozzles were considered or modeled, but the selection of break locations to maximize the various available debris types suggests that much of the reactor vessel insulation is reflective metal insulation (RMI), or most of the insulation in the reactor cavity would remain trapped and not transport to the strainer, or the pipes are so restrained that any breaks would be effectively smaller than breaks in the SG cavities.

For ANO-1, the licensee stated that the break selection process was revisited after modifications were made to reduce debris generation for problematic debris types. Four breaks (S1, S3, S4, and S5) were found to produce the most fibrous insulation debris (within 10 percent of each other). The licensee also chose one break to maximize coating debris (S5). The final debris type that the licensee evaluated was Cal-Sil. The licensee stated that break S4 produced the most Cal-Sil debris. Head loss testing determined that break S4 generated the limiting debris load, but ultimately the testing included bounding amounts of each debris type. This methodology provides margin for any future changes in the debris generation analysis.

For ANO-2, the licensee stated that the break selection process was revisited to reflect modifications made to reduce debris generation for various debris types. The break locations listed above, for ANO-2, are the potential limiting locations for various debris types. The licensee stated that breaks were evaluated to ensure that the limiting break for particulate and fibrous debris types were identified. Break S6 is limiting for the generation of Cal-Sil. The surge line break, S4, was found to produce the maximum quantity of fibrous debris.

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 ANO 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 September 29, 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 5.45D for stainless steel clad and banded Cal-Sil insulation. In this case D refers to the internal pipe diameter. In more general cases D is based on the size of the break opening.

The licensee stated that a ZOI of 25D was used for Cal-Sil insulation with cladding secured with sheet metal screws in lieu of banding. The licensee stated that Westinghouse performed jet impingement testing at Wyle Labs test facility (WCAP-16836-P Revision 0, “Arkansas Nuclear One - Jet Impingement Testing of Insulating Materials” (Proprietary), which has not been reviewed by NRC staff) that demonstrated satisfactory performance of this insulation system at 25D. The licensee also stated that a ZOI of 25D was used for Thermal-Wrap fiber and high-density fiberglass (HDFG) insulation with metal sheeting held in place with sheet metal screws. The licensee further stated that these insulation systems were equivalent to the Cal-Sil insulation covered by sheet metal fastened by sheet metal screws that had been tested and did not fail at 25D. These insulation systems include a jacketing that is held in place with screws rather than banding, and it is likely that it would withstand the very low destructive pressure associated with the 25D ZOI and the ZOI size would include nearly the entire volume of a SG cavity.

The licensee stated that a ZOI of 5.45D was assumed for an insulating system involving Thermal-Wrap batting and blankets covered with a stainless steel sheet held in place with banding. The licensee's justification was that this insulation system would be as damage-resistant as the jacketed and banded Cal-Sil insulation for which the GR/SE provides a 5.45D ZOI, based on the Ontario Power Group (OPG) testing. This is because the sheeting is stainless steel rather than aluminum and, even if breached, the fiberglass blanket material would protect against release of the internal fiberglass batting.

The licensee assumed a ZOI of 7D for Transco Thermal-Wrap blankets and stated that there was no guidance associated with this insulation system. This insulation system was identified only in ANO-2.

The licensee assumed that Cera-fiber has the same ZOI as Cal-Sil (i.e., 5.45D if banded and 25D if unbanded). This insulation type was only identified as being installed in ANO-2 in relatively small amounts.

The licensee identified the quantity of signs, placards, tags, tape, and similar foreign material that could transport to the strainers as being less than 100 ft^2 with a strainer qualification testing sacrificial area of 200 ft^2.

<u>ANO-1 Review</u>

On May 21, 2009, the NRC staff issued three RAIs (A.1–A.3). On September 24, 2009, the licensee responded to the RAIs. The discussion below describes the RAIs and responses in more detail.

In RAI A.1, the NRC staff requested the licensee to provide a more detailed summary of the basis for assuming a 5.45D spherical ZOI insulating system involving Thermal-Wrap batting and blanket covered with banded stainless steel jacket. The NRC staff requested the licensee to address uncertainties associated with the original OPG testing used to establish the 5.45D ZOI (e.g., scaling of the jet size to the target, determination of damage pressure in the test, and determination of damage threshold). In its response, the licensee provided information showing that the installation of the Thermal-Wrap is more robust than the insulation system tested at OPG. In addition, the licensee pointed out that the Thermal-Wrap has an additional barrier to damage in the form of a heavy fabric cloth that contains the fibrous insulation. With respect to the uncertainties associated with the OPG testing scaling, the licensee stated that the uncertainties were addressed by the assumption that 100 percent of the material within the ZOI is rendered into fines and very small pieces making it 100 percent transportable. The licensee also stated that the 5.45D ZOI was determined using the impingement angle that enhanced debris generation. In reality, the impingement angle would be random and testing at other angles resulted in lower debris generation. The NRC staff finds that the licensee's justification was acceptable based on the details of the installation and construction details provided by the licensee, and the licensee's assumption that 100 percent of the debris is created as small and fine debris. The NRC staff also finds that the use of the 5.45D ZOI for Thermal-Wrap for ANO-1 is reasonable. The NRC staff also noted that the debris was added as fines to the ANO testing, which resulted in additional conservatism. The NRC staff found the response to this RAI acceptable.

In RAI A.2, the NRC staff stated that the testing for Transco Thermal Wrap discussed in the February 28, 2008, supplement indicated that a 7D ZOI was assumed for ANO-2. The NRC staff requested the licensee to explain the ZOI assumptions for these insulation systems, which were different between units. In its response, the licensee stated that the Thermal-Wrap is installed not on piping, but on the pressurizer, and explained that the testing was conducted specifically on the pressurizer insulation system and not on piping insulation. The NRC staff reviewed the licensee's response and found it acceptable.

In RAI A.3, the NRC staff requested the licensee to provide a more detailed summary of the basis for assuming a 2D spherical ZOI for insulating systems involving Temp Mat™ covered with standard Transco jacketing and fasteners (similar to the surrounding RMI). In its response, the licensee stated that the fibrous material would not be released unless the outer jacket was dislodged, and that the material contained within the outer jacket would have no significant effect on the ability of the outer jacket to withstand the energy from an impinging jet. The licensee stated that the panels containing Temp Mat™ were identical in construction to the RMI panels, and that they were installed in limited locations where RMI thickness was limited due to interferences. The licensee also provided details of the location of the installation of the jacketed Temp Mat™ that justify that the use of the small ZOI would have little effect on the overall debris generation for the material. The licensee also stated that all fiber (from all sources) within the ZOI is assumed to be 100 percent fines and very small pieces that transport fully to the strainer, which provides a large conservatism to the overall evaluation. The licensee also stated that the amount of additional fiber available for destruction within the SG cubicle is small and that excess fiber was added to the head loss test as a conservatism. The extra debris in the head loss test would account for all potential debris created from encapsulated Temp Mat™ within the SG cubicle.

The NRC staff reviewed the licensee's response and found that the licensee had not justified the assumption of a 2D ZOI for encapsulated Temp Mat™. However, the NRC staff determined that the licensee included adequate conservatisms to assure that the overall head loss in the analysis is conservative.

On September 29, 2010, the licensee submitted an update to its assumptions for ZOIs for various insulation types. It changed its assumption for Cal-Sil and HDFG within stainless steel lagging secured with sheet metal screws from 25D to infinite. This means that all Cal-Sil and HDFG in containment, protected with this system is assumed to be damaged by a jet unless it is shadowed by a robust barrier. The Thermal-Wrap installed within stainless steel lagging secured with sheet metal screws was originally assigned a ZOI of 25D. This ZOI was reduced to 17D. The NRC staff reviewed the updated assumptions and determined that they were either conservative or were consistent with the GR/SE. The submittal also stated that the Temp Mat™ ZOI was revised from 2D to 11.7D. This is a change from the position presented in response to RAI A.3, but is consistent with the GR/SE.

The licensee also stated that they no longer credited testing conducted by Westinghouse to determine ZOIs for various materials.

Finally, in its letter dated September 29, 2010, the licensee stated that the amount of miscellaneous materials in containment was changed from 100 ft^2 to 148.2 ft^2, which equates to 111.2 ft^2 of strainer blockage. This is within the 200 ft^2 assumed in the strainer testing. The NRC staff concludes that this change is consistent with other assumptions in the overall analysis.

ANO-2 Review

In RAI B.1, the NRC staff requested the licensee to explain what it means to position the target with its center 90 degrees (°) from the jet. The NRC staff also requested the basis for this position being the most limiting since previous information indicated that a seam orientation of 45° is the most limiting. In its response, the licensee provided information regarding the testing conducted on the insulation. The licensee stated that the insulation was not installed on piping but mocked up to represent installation on a larger component, specifically the pressurizer. The orientation of the insulation was the impingement angle of the jet with respect to a flat insulation blanket. The orientation had to be modified during testing because the 45° angle resulted in the ejection of the insulation from the test fixture. Ensuing tests with a 90° angle orientation maintained the insulation in the test stand so that the jet impinged the insulation blanket for the entire duration of the blowdown. The licensee stated that the angle of impingement on the flat blanket was not considered to have a significant effect on the failure of the insulation during testing. The NRC staff reviewed the licensee's response and found it acceptable.

In RAI B.2, the NRC staff requested the licensee to provide details on the testing that justified the ZOI reductions for Transco Thermal Wrap. The NRC staff referenced a list of questions developed based on concerns with Westinghouse testing conducted at Wyle Labs because they were applicable to the ANO testing. This issue is also related to RAI B.3, which is discussed below.

The licensee stated that the debris generation evaluation for ANO-2 used a 7D ZOI for Thermal-Wrap insulation. The licensee used test results from ZOI testing conducted at equivalent ZOIs of 7D and 12D to evaluate the potential for debris generation. Original NRC guidance had set the ZOI for Thermal-Wrap at 17D. The licensee stated that the amount of debris potentially created by Thermal-Wrap installed in ANO-2 would not be affected by applying different ZOIs between 7D and 12D because the Thermal-Wrap is installed in discreet locations in the ANO-2 containment. The licensee stated that it would rather resolve the Thermal-Wrap ZOI issue on a plant-specific basis than wait for the industry's generic resolution for ZOI testing.

One alternate strainer head loss test conducted for ANO-2 included a bounding quantity of Thermal-Wrap based on a 17D ZOI. This test included less Cal-Sil than the design-basis test but included adequate Cal-Sil to account for the maximum amount currently predicted to reach the strainer. The test that included the 17D amount of Thermal-Wrap resulted in lower head loss for two of the three analyzed conditions for ANO-2 when compared to the design-basis test. For the third condition (full low pressure safety injection (LPSI) flow), the Thermal-Wrap case had a slightly higher head loss but did not exceed the allowable. The NRC staff reviewed the licensee's response and found the ZOI for Thermal-Wrap, as applied within the ANO-2 analysis, to be acceptable.

In RAI B.3, the NRC staff requested the basis for assuming a ZOI of 7D when testing showed that the insulation could be dislodged at a ZOI of 12D. In its response, the licensee provided additional information on the testing. There were two tests conducted at a 12D-equivalent ZOI. The first of these tests resulted in the insulation being ejected from the test stand. The second test was conducted in a reconfigured test stand, which ensured that the insulation was not ejected and remained in the jet for the entire blowdown period. Neither test resulted in the release of any insulation. A third test at an equivalent 7D ZOI was conducted. This test resulted in some slight tearing of the outer jacket and the extrusion of a small amount of insulation through a failed seam. The licensee stated that the damage was not a result of the interaction between the jet and the blanket but resulted from interactions with the test stand. Therefore, a ZOI of 7D was adopted. Within the ZOI, the licensee assumed that the insulation would be rendered into fines and very small pieces. The NRC staff reviewed the licensee's response and stated that the staff does not generically accept 12D or 7D as an acceptable ZOI for Thermal-Wrap insulation at this time. However, the NRC staff finds that for the ANO-2 installation, the overall head loss evaluation was conducted such that even if a 17D ZOI (current staff approved ZOI) were applied to Thermal-Wrap, the overall analysis would retain margin. Therefore, the NRC staff finds the licensee's response to RAI B.3 acceptable as applied only to ANO-2.

On September 29, 2010, the licensee submitted an update to its assumptions for ZOIs for various insulation types. It changed its assumption for Cal-Sil within stainless steel lagging secured with sheet metal screws from 25D to infinite. This means that all Cal-Sil in containment, protected with this system is assumed to be damaged by a jet unless it is shadowed by a robust barrier. The ZOI for Thermal-Wrap blankets was changed from 7D to 17D. The ZOIs for ceramic fiber insulation were changed to be consistent with ZOIs for Cal-Sil with similar installation systems. That is, the insulation protected with sheet metal screws was all assumed to be damaged (if not protected by a robust barrier), and that within a banded lagging system was assigned a 5.45D ZOI. The NRC staff reviewed the updated assumptions and determined that they were either conservative or consistent with the applicable guidance.

The licensee also stated that they no longer credited testing conducted by Westinghouse to determine ZOIs for various materials.

Finally, in its letter dated September 29, 2010, the licensee stated that the amount of miscellaneous materials in containment was changed from 100 ft^2 to 122.3 ft^2, which equates to 91.8 ft^2 of strainer blockage. This is within the 200 ft^2 assumed in the strainer testing. The NRC staff concludes that this change is consistent with other assumptions in the overall analysis.

NRC Staff Conclusion

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

5.0 DEBRIS CHARACTERISTICS

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

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through September 29, 2010.

ANO-1 Review

The potential debris sources at ANO-1 include Transco RMI, Transco Temp Mat™, Cal-Sil, HDFG, Thermal Wrap, and fabric blankets in penetrations. The NRC staff observed that the licensee assumed different ZOIs for some of these materials than that which was approved in the SE on NEI 04-07. For instance, a 2D ZOI was assumed for a few small sections of Temp Mat™ with similar jacketing to the surrounding RMI. The NRC staff noted that a 60/40 split between small and large pieces that was approved for a larger ZOI does not seem conservative for this material within a 2D ZOI, since the fraction of fines and small pieces could be substantially higher. Thermal Wrap insulation with stainless steel jacketing and banding was assumed to have a ZOI of 5.45D. This ZOI was based on OPG data for Cal-Sil insulation. The NRC staff also noted that the basis for assuming a 60/40 split between small and large pieces of Thermal Wrap does not seem to be adequately justified for a reduced ZOI.

The NRC staff further noted that the licensee assumed that 10 percent of fabric blankets in penetrations would be destroyed into fines. The approved guidance considers it appropriate to assume 100 percent fines for untested debris targets, and as such, the licensee's assumption appears to be a deviation from the approved guidance.

On May 21, 2009, the NRC staff issued RAI A.4 for this area. The NRC staff requested a technical basis for the 10 percent fines assumption for penetration fabric. In addition, the NRC staff requested the licensee to identify the size distribution of the remaining 90 percent of this material.

The licensee stated the following points to support its position that 10 percent is conservative:

- Fiber blankets are a significant distance from limiting breaks (hot legs), approximately 14D. Closer cold leg breaks do not result in a more limiting total fiber load even if more penetration fiber is destroyed.
- It is more likely to remain as intact sheets, and there is large margin for miscellaneous sacrificial debris blockage.
- The material is heavy-weight and was not observed to become damaged significantly in destruction tests.
- The K-Wool value may be representative, with a 24 pounds per square inch gauge (psig) and 5.4D ZOI.
- Ten percent of fabric was accounted for in tests as low density fiberglass fines.

The NRC staff reviewed the response and found it acceptable based on the information provided by licensee, particularly the distance of the material from the limiting hot leg break, the fact that there is only a small amount of the material in the containment (approximately 2 pound-mass), and other conservatisms in the analysis.

In its letter dated September 29, 2010, the licensee stated that the size distribution for Thermal-Wrap and Temp Mat™ was being revised from 100 percent fines to 60 percent fines and 40 percent large pieces due to an increase in the ZOI size. The fines are assumed to transport 100 percent to the strainer. This is consistent with NRC staff guidance or conservative.

ANO-2 Review

The potential debris sources reported at ANO-2 include Transco RMI, Mirror RMI, Transco Thermal Wrap, Cera-fiber, and Cal-Sil. The NRC staff found that the size distributions for RMI and Cal-Sil were not consistent with guidance. However, the NRC staff also found that the RMI is not a head loss challenge and that the assumptions for its size distribution were not consequential to the analysis. The NRC staff concluded that it required additional information to evaluate the acceptability of the Cal-Sil size distribution, which was stated to be based on data from NUREG/CR-6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," dated February 2003 (ADAMS Accession Nos. ML030780733 and ML030920540).

In addition, the NRC staff observed that the licensee assumed a different ZOI for Thermal Wrap than was approved in the SE on NEI 04-07 based on testing at Wyle Labs. The NRC staff noted that the size distribution for destroyed Thermal Wrap did not appear to take into account the higher ZOI-averaged destruction pressure associated with the reduced ZOI, and the potential for this higher destruction pressure to result in increased fragmentation of debris.

On May 21, 2009, the NRC staff issued RAI B.4 for this area. The NRC staff requested a technical basis for the assumption that 40 percent of the Cal-Sil becomes fines and 60 percent is generated as large pieces. In addition, the NRC staff requested the licensee to provide a comparison between the assumed Cal-Sil debris size distribution and the sizes of the Cal-Sil pieces used in the erosion testing program that shows that the tested size distribution is prototypical or conservative. By letter dated September 24, 2009, the licensee responded to the RAI. The licensee provided background information concerning the basis for the NEI 04-07 size distribution, including the OPG data and the associated uncertainties. The licensee also provided NUREG/CR-6808 data from steam testing, which came from OPG two-phase testing and Studsvik jet erosion testing.

The licensee provided the following additional information in support of its 40 percent small fines assumption:

- A 25D ZOI for non-banded Cal-Sil was used, and over 2/3 of generated Cal-Sil is this material.

- A 5.45D ZOI was applied to stainless jacketed Cal-Sil, whereas the SE-approved value was based on aluminum jacketed tests (this material produces about 10 percent of damaged Cal-Sil).

- Studsvik jet erosion testing showed no erosion beyond about 9 psig, corresponding to a 12D ZOI.

- OPG test data showed amounts of small pieces and fines less than the 40 percent assumption.

- OPG tests used limiting 45° seam angle, whereas plant practice is to orient seam downward.

- The remaining 20 percent of Cal-Sil generated comes from spray or submergence generated material that is not jacketed but covered with mastic cement that would break down over time.

The NRC staff reviewed the response and found it reasonable based on the following primary factors: (1) the majority of Cal-Sil is generated within a 25D ZOI, so that most of it is exposed to a relatively low pressure jet, (2) Studsvik erosion test data showing that jet erosion of unjacketed Cal-Sil ceases beyond about 9 psig, and (3) use of the limiting seam angle in the OPG testing. The NRC staff also considered conservatisms associated with the transport and erosion of Cal-Sil, as well as the treatment of the transported material as fine powder in head loss testing as other conservatisms that factored into the acceptance of the licensee position.

In its letter dated September 29, 2010, the licensee stated that the size distribution for Thermal-Wrap and Temp Mat™ was being revised from 100 percent fines to 60 percent fines and 40 percent large pieces due to an increase in the ZOI size. The fines are assumed to transport 100 percent to the strainer. This is conservative with respect to NRC staff guidance.

NRC Staff Conclusion

For the debris characteristics review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris characteristics evaluation for ANO 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 September 29, 2010.

ANO-1 Review

The licensee stated that walkdowns were performed at ANO-1 to collect samples throughout the reactor building on a wide variety of surfaces and at various elevations to document potential debris in accordance with NEI 02-01, “Condition Assessment Guidelines: Debris Sources Inside PWR Containments,” dated April 19, 2002 (ADAMS Accession No. ML021490241). The licensee also stated that latent debris surveys were performed in two consecutive outages with consistent results.

Per the guidance in NEI 04-07, the licensee assumed that 15 percent of the latent debris is comprised of fiber and the remaining 85 percent is comprised of particulate. Walkdown data was not available for the grating areas. Therefore, the floor attributes were conservatively applied to the grating area.

Based on the data, the amount of latent debris is estimated to be 122.4 pounds (lb). Strainer qualification testing used a latent debris loading of 170 lb of particulate and at least 15 lb of fiber (depending on the break). Strainer qualification tests included margin for both fiber and particulate material that could be allocated to address larger latent debris totals in the future, if necessary. The licensee tracks the total fiber load, not just latent fiber. The assumptions for fibrous debris loading for the limiting breaks are shown in Table 3.f.5-1, “Comparison of Debris Generation to Strainer Test Debris Loads,” of the letter dated September 15, 2008.

The total surface area of signs, placards, tags, tape, and similar foreign materials in the containment following efforts to remove these potential debris sources is approximately 31.8 ft^2, which is well below the 200 ft^2 allowed for foreign material blockage in the strainer qualification tests.

On May 21, 2009, the NRC staff issued RAI A.5 for this area, requesting details of the latent debris sampling and evaluation methodology. By letter dated September 24, 2009, the licensee responded to the RAI. The licensee stated that the latent debris sampling and data analysis involved dividing the reactor building into different types of surfaces, calculating the areas of each surface type, and extrapolating sample results to the total areas for each surface type. Each sample was obtained by wiping the sample surface area with a clean Masslin cloth at representative accessible areas. Fifty samples were taken from the twelve types of areas. The samples were taken prior to cleanup of the containment to ensure bounding values were obtained.

The data was statistically analyzed and a 90 percent confidence upper limit was obtained. The areas within the reactor building were multiplied by the appropriate adjusted unit surface loading to get the total latent debris on each surface type. The total debris for each surface type was added together to obtain the total containment latent debris load.

The NRC staff reviewed the response and concluded that the licensee's methodology is consistent with latent debris sampling guidance in NEI 02-01, which was evaluated by the NRC staff and found to be acceptable. This conclusion was based on the licensee description of the sampling performed. In addition, the head loss testing and analysis included margin for additional particulate and fiber debris beyond the calculated amount. The amount of latent debris used in the analysis was 200 lb, which provides margin compared to the quantity calculated based on sampling. The licensee did not assign absolute values to latent debris amounts but included total particulate and fibrous margins in the evaluation.

ANO-2 Review

The licensee stated that walkdowns were performed at ANO-2 to document potential debris in accordance with NEI 02-01. Per the guidance in NEI 04-07, 15 percent of the latent debris is assumed to be fiber, and the remaining 85 percent is assumed to be particulate. Walkdown data was not available for the grating areas. Therefore, the floor attributes were conservatively applied to the grating area.

Based on data collected in the walkdowns, the amount of latent debris was estimated to be 47 lb. Strainer qualification testing used a latent debris loading of approximately 115 lb, to provide margin to the measured values.

The total surface area of signs, placards, tags, tape, and similar foreign materials in the containment, following efforts to remove these potential debris sources, is approximately 35 ft^2, which is well below the 200 ft^2 allowed for foreign material blockage in the strainer qualification tests.

By letter dated May 21, 2009, the NRC staff issued RAI B.5 for this area, requesting details of the latent debris sampling and evaluation methodology. By letter dated September 24, 2009, the licensee responded to the RAI. The licensee stated that the latent debris sampling and data analysis involved dividing the reactor building into different types of surfaces, calculating the areas of each surface type, and extrapolating the sample results to the total areas for each surface type. Each sample was obtained by wiping the sample surface area with a clean Masslin cloth at representative accessible areas. Forty-two samples were taken from the twelve types of areas. The samples were taken prior to cleanup of the containment to ensure bounding values were obtained.

The data was statistically analyzed, and a 90 percent confidence upper limit was obtained. The areas within the reactor building were multiplied by the appropriate adjusted unit surface loading to get the total latent debris on each surface type. The total debris loads for each surface type were added together to obtain the total containment latent debris load.

The total latent debris calculated is based on measurements taken during the 1R20 spring 2007 refueling outage (RFO), which was approximately 47 lb. This quantity is consistent with the latent debris total measured during the previous outage. The head loss testing and analysis included margin for particulate and fiber debris in excess of this amount by assuming that there is 150 lb of latent debris in containment. The licensee did not assign absolute values to latent debris amounts, but included total particulate and fibrous margins in the evaluation.

The NRC staff reviewed the response and found that the methodology used was acceptable. This conclusion was based on the licensee's methodology being consistent with the NEI 02-01 guidance. The licensee's RAI response identified the number, type, or location for the samples taken. The NRC staff verified the details of the methodology to assure consistency in the licensee information regarding the latent debris quantity value used during strainer performance testing.

In its letter dated September 29, 2010, the licensee stated that an additional latent debris survey was conducted that found 139.7 lb of latent material in ANO-2. The updated amount does not result in the loss of adequate margins in the evaluation.

NRC Staff Conclusion

For the latent debris review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the latent debris evaluation for ANO 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 September 15, 2008, for ANO-1 and September 24, 2009, for ANO-2, and the update to the final response dated September 29, 2010.

ANO-1 Review

The licensee originally assumed 100 percent debris transport. This is a conservative method and is therefore found to be acceptable by the NRC staff.

In its letter dated September 29, 2010, the licensee revised its transport analysis to account for a different size distribution for Temp Mat™ and Thermal-Wrap. The licensee had previously assumed that these debris types were 100 percent fines when generated. The licensee subsequently increased the ZOIs for these materials. Therefore, the conservative assumption of 100 percent fines was abandoned. Using the NRC staff-approved ZOIs for these material types, the licensee assumed that 60 percent of the material was rendered into fines and 40 percent remained intact. The entirety of the fines (100 percent) were assumed to transport to the strainer. This treatment is considered conservative by the NRC staff because a significant portion of the debris assumed to be fines would actually be generated as small pieces and would not fully transport to the strainer.

Therefore, the ANO-1 debris transport analysis is acceptable.

ANO-2 Review

The licensee stated that debris is assumed to be blown down to the containment pool. Therefore, a detailed model of washdown was not performed. The licensee did not credit inactive holdup volumes for pool fill-up. For recirculation, the licensee used a computational fluid dynamics (CFD) model. Only one break was analyzed, because it would result in the greatest flow out of the D-rings due to the direction of the break flow. This results in the greatest transport to the strainer.

The licensee performed erosion and transport testing with Cal-Sil debris at Fauske and Associates Labs (Fauske Labs). The licensee stated the test material was the same as that installed at ANO-2.

The initial debris transport fractions were reported as follows:

- Assumed 100 percent transport of latent debris, qualified and unqualified coatings, and fiber fines
- RMI transport was discussed, but not considered important to head loss

- Assumed 71 percent transport of Thermal-Wrap small and large pieces; however, 100 percent transport was considered for the strainer test inputs

- Assumed 49 percent transport of Cal-Sil for the first 3 days and 76 percent at 30 days

In its letter dated September 29, 2010, the licensee stated that 100 percent of the Cera-fiber is also assumed to transport to the strainer.

By letter dated May 21, 2009, the NRC staff issued RAIs B.6–B.10. By letter dated September 24, 2009, the licensee responded to the RAIs. The discussion below describes the RAIs and responses in more detail.

In RAI B.6, the NRC staff requested that the licensee provide information that shows that the Cal-Sil transport testing for ANO-2 was conducted in a prototypical or conservative manner with respect to expected plant conditions. In its response, the licensee assumed 100 percent of Cal-Sil fines transport to the strainer. The NRC staff reviewed the response and found it acceptable.

In RAI B.7, the NRC staff requested the licensee to address whether and to what extent issues identified in an audit report dated August 12, 2008, for Salem Nuclear Generating Station, Units 1 and 2 (ADAMS Accession No. ML082170506) affected the erosion testing for ANO-2 conducted at Fauske Labs. In its response, the licensee adopted a new assumption of 30 percent erosion and provided test results and conservatisms contained within the debris generation analysis that support this position. The NRC staff reviewed the response and found it acceptable.

In RAI B.8, the NRC staff stated that based on the licensee's supplemental response dated September 15, 2009, it appeared that only one CFD analysis was performed for ANO-2. The NRC staff requested that the licensee provide a basis for considering this single simulation to be the bounding case. In its response, the licensee provided several corrections to previous information. The licensee stated that multiple CFD runs had been performed and that the case presented was representative of a bounding case. The licensee also stated that the total flow rate out of the D-rings was not dependent on break flow direction. The licensee also stated that the CFD was not credited to a significant extent since most debris was considered to fully transport, whereas only pieces of Cal-Sil were considered for settlement. The NRC staff reviewed the response and found it acceptable.

In RAI B.9, the NRC staff requested that the licensee justify that the single failure of a LPSI pump to trip at the switchover to recirculation can be addressed by the plant staff in 30 minutes. The NRC staff also noted that the flow from a LPSI pump did not appear to be considered in the debris transport calculation. The NRC staff also questioned whether emergency operating procedures would either direct or allow plant operators to operate an LPSI pump in recirculation mode under design-basis conditions and to evaluate this condition, if applicable. In its response, the licensee stated that head loss testing included flow from an LPSI pump failure to trip and that the debris transport results would not have changed due to consideration of LPSI pump flow due to 100 percent transport for most types of debris. The licensee stated that the additional flow from the LPSI pump would not result in the transport metric for Cal-Sil pieces to be exceeded. The licensee noted that the Cal-Sil erosion testing was performed at velocities significantly in excess of the Cal-Sil piece bulk tumbling velocity and that most of the pieces would tumble to low velocity regions, such that the velocities used for the erosion testing remain bounding. Finally, the licensee stated that emergency operating procedures instruct operators to confirm LPSI pumps have stopped and do not include direction or allowance for LPSI pump restart in recirculation mode. The NRC staff reviewed the response and found it acceptable.

In RAI B.10, the NRC staff stated that the debris transport results for Thermal Wrap insulation, while provided in the licensee's letter dated February 26, 2009, were not provided in the corresponding table in the licensee's letter dated September 15, 2009. The NRC staff questioned the assumptions for transport of this debris type. In its response, the licensee stated that the reason the Thermal Wrap was not included was because it was not generated by the limiting break (S6, cold leg break). The Thermal Wrap remains installed in the plant and can be generated by a less limiting break (S4, pressurizer surge line). At one time the S4 break was considered to be the limiting break, but after insulation modifications including banding, replacement, and removal of insulation, the S6 break became limiting as determined by head loss testing. The licensee assumed 100 percent transport of the Thermal-Wrap for the less limiting break. The NRC staff reviewed the response and found it acceptable.

In its letter dated September 29, 2010, the licensee provided the following transport metrics for ANO-2:

- Latent debris, qualified and unqualified coatings, and Cera-fiber transport of 100 percent
- Thermal-Wrap fiber transports 60 percent (60 percent is generated as fines and all of that transports)
- Cal-Sil – break generated transports 58 percent (100 percent of the fines transport)
- Cal-Sil – spray generated transports 30 percent (100 percent of the fines transport)

The NRC staff considers these transport metrics to be acceptable for the ANO-2 conditions to which they were applied.

NRC Staff Conclusion

For this review area, the licensee provided information such that the NRC staff has reasonable assurance that the debris transport has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris transport evaluation for ANO 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 September 29, 2010.

ANO-1 Review

The licensee replaced the original sump strainer with passive Control Components Inc. (CCI) strainer modules with an area of 2,715 ft^2 to reduce head loss. The concentration of the sodium hydroxide buffer was reduced to limit the amount of chemical precipitates that could form and transport to the strainer. The NRC staff witnessed some of ANO-1's head loss testing during a visit to Fauske Labs in August of 2007. The NRC staff found that the testing was generally conducted using procedures that would produce prototypical or conservative head loss values, as well as procedures that reflected incorporation of NRC staff comments made during interactions with industry.

The amount of fibrous debris that transports to the strainer is relatively small. However, the potential for the formation of a filtering bed exists. The ANO-1 containment has a significant amount of Cal-Sil insulation. Testing has shown that even a very thin bed of fiber, in conjunction with Cal-Sil, can result in significant head losses. A sacrificial area of 200 ft^2 was included for test scaling purposes. The flow through the strainer was stated to be about 9,734 gallons per minute (gpm), but testing was conducted at a scaled flow of about 10,280 gpm. The corresponding approach velocity is about 0.008 feet per second (ft/sec) for 9,734 gpm flow. The design limit for strainer head loss is based on NPSH margin at higher temperatures and strainer structural strength at lower temperatures after chemical effects have formed.

The clean strainer head loss (CSHL) value is very low because the strainer is installed over the sump and water flows directly out of the plenum into the sump below. The licensee claimed that the CSHL was negligible, and that the strainer exit loss was included in the NPSH calculation.

The licensee also noted that the strainer is fully submerged by at least 7 inches (in.) at the onset of recirculation during a small break LOCA (SBLOCA). The analysis and testing for vortexing was completed using this value. However, the sump level calculated for this submergence includes coolant volume from the accumulators. Some breaks may not have this volume available during all times that recirculation is required.

The ANO-1 sump is not vented to the atmosphere above the minimum containment water level and is completely submerged at the onset of recirculation.

The initial ANO-1 flashing evaluation credited accident pressure to assure that no flashing would occur during recirculation. The evaluation stated that the sump remains subcooled relative to reactor building pressure throughout the event response.

The licensee stated that during testing, all fibrous debris was rendered into fines and very small pieces. In addition, the licensee stated that fibrous debris was added in a manner to prevent agglomeration of the fines and small pieces. The licensee provided the amounts of debris assumed to be present in the plant. The amounts of debris used in testing were scaled based on the ratio of the strainer areas in the test and the plant (test/plant). The licensee stated that testing conducted with lower amounts of fiber did not result in higher head losses than the testing conducted with the full fiber load. The licensee stated that manual agitation was used to keep debris in suspension until it reached the strainer.

In the chemical effects area, the licensee stated that during chemical effects testing, the head losses exceeded the capacity of the test facility. In order to continue the test, the flow rate was decreased to reduce head loss. Additional chemicals were added to the test until the entire chemical term was introduced to the flume. Flow sweeps were conducted to determine whether bore holes had occurred. The flow sweeps indicated that bore holes had not occurred during the test. The results of the test were extrapolated to a higher flow rate based on a velocity correlation. The licensee stated that at higher head losses, bore holes or channeling could occur, which would reduce head loss. The NRC staff noted that this is one possible outcome. However, higher flow rates also result in additional compaction of a debris bed and can increase head loss. The total chemical head loss was reported to be slightly less than 8 feet (ft) at full flow conditions. The head loss without chemical effects was measured at a full scaled flow rate and was about 0.4 per square inch (psi), or slightly less than 1.0 ft of head.

By letter dated May 21, 2009, the NRC staff issued RAIs A.6–A.9. By letter dated September 24, 2009, the licensee responded to the RAIs. The discussion below describes the RAIs and responses in more detail.

In RAI A.6, the NRC staff noted that the testing conducted by Fauske Labs used a debris addition sequence that was potentially non-prototypical and non-conservative. The licensee performed sensitivity testing on the debris addition sequence. The NRC staff stated that it is possible that the addition of fibrous debris first would not result in non-conservative results based on the relatively low available fiber at ANO-1. The NRC staff requested the licensee provide the information regarding the sensitivity testing or other analyses showing that the addition of fibrous debris prior to other types of debris is conservative or at least neutral to the ANO test results. In its response, the licensee stated that, due to limited fibrous debris quantities, only thin bed conditions are possible for ANO-1 and that the total available fiber results in less than a 1/8-inch theoretical bed. The licensee stated that the fibrous debris was rendered into fines and very small pieces, the debris was well diluted prior to and during addition to the test to prevent agglomeration, and the debris was added very slowly and observed through a clear test tank to verify its distribution. The debris preparation and introduction were carefully controlled to maximize an even distribution of fiber over the strainer.

The licensee conducted several tests with varying fibrous debris amounts to determine the limiting fiber load and noted that the head loss would remain very low until a sufficient amount of fibrous and particulate debris was available at the strainer, at which point head loss would begin to increase.

The licensee stated that inspections of the debris beds following the tests showed that the beds were fully formed and evenly distributed such that conservative head loss results were attained.

The licensee referenced guidance provided in the "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing" for producing the most limiting head loss from a thin bed (ADAMS Accession No. ML080230038). This guidance states that higher head losses may occur if a uniform fibrous debris bed is formed prior to the addition of particulate debris. The licensee also stated that there is adequate confidence, based on multiple tests (more than 20), that a conservative head loss was attained for the potential debris loads for the ANO-1 strainer.

The NRC staff reviewed the licensee's response and based on the observations of a uniform debris bed, the particulate to fiber ratios in the testing, and the rigorous test program conducted by the licensee, the NRC staff has confidence that the head loss measured during the ANO-1 qualification test represents a conservative value.

In RAI A.7, the NRC staff requested the licensee to provide the minimum strainer submergence that could occur if the core flood tank (CFT) volume is not included in the sump inventory. The NRC staff also requested the licensee to verify that the vortexing and flashing evaluations bound this condition, and alternatively, to verify that recirculation is not required for all events where the accumulator volume is not fully discharged to the RCS/sump. In its response, the licensee stated that if the RCS pressure was too high to prevent the CFTs from discharging into the RCS, only the high-pressure injection (HPI) pump (500 gpm) would be able to inject. At lower RCS pressures that would occur with larger breaks the low-pressure injection (LPI) pumps (3,000 gpm) would also inject. At the higher RCS pressure, the flow through the strainer would be significantly reduced.

The licensee stated that the strainer would remain submerged even if the CFTs are not credited with providing inventory to the sump pool. Submergence would be reduced by 3 inches, from 7 inches to 4 inches, with no CFT inventory credited.

The licensee's limiting evaluation is based on a 36-inch hot leg break. A break small enough to result in RCS pressure staying above the CFT dump pressure would have to be about 3.3 inches or smaller. The 3.3-inch break would result in the CFTs dumping about 25 minutes after the break. The 3.3-inch break would also result in significantly lower debris amounts available to potentially build a bed on the strainer.

The licensee evaluated both the potential for vortexing and flashing, and determined that the existing analysis bounds the potential for these phenomena at lower sump levels if the lower flow rates and lower potential for debris generation are considered. The licensee's test program and analytical evaluation showed that vortex formation would not occur at 4 inches of submergence even at the design flow rate. The licensee's flashing evaluation stated that the reduced debris load would likely result in reduced head loss that would offset the small decrease in strainer submergence. If the head loss did not decrease due to the reduced debris load, a small credit for pre-existing containment pressure on the order of magnitude of that already described in the licensee's supplemental response would be needed.

The NRC staff reviewed the licensee's response and based on the staff's review of the licensee's calculation that shows that the strainer remains fully submerged, and the licensee's evaluation that the potential for vortex formation and flashing across the debris bed remain bounded by previous evaluations, the staff found the response acceptable.

In RAI A.8, the NRC staff requested the licensee to clarify the purpose of Table 3.b.4-1, "Summary of Loss-of-Coolant Accident (LOCA)-Generated Debris," in its letter dated September 15, 2008, and verify that the amounts of debris used in testing were scaled from debris amounts that were predicted for the various breaks considered. In its response, the licensee stated that the table was intended to provide "less than" limits for each debris type such that the amounts at the bottom of the table bounded the potential total fiber amounts for each break. These amounts were used to determine the test debris loads. The licensee provided an updated table containing actual debris generation numbers. The NRC staff reviewed the licensee's response and noted that the updated table format can be understood by staff and is consistent (with some refinements) with other debris generation values presented by the licensee. The NRC staff also noted that the amounts of debris added to the head loss testing bounded the expected plant debris generation values. Therefore, the NRC staff found the response acceptable.

In RAI A.9, the NRC staff requested the licensee to provide, in more detail, the extrapolation methodology for the peak head loss including assumptions made regarding how increased flow velocities affect debris bed formation and compression, and therefore, head loss. In its response, the licensee clarified that all of the non-chemical and two batches of chemical debris were added prior to reducing the flow in the test. The licensee stated that bore holes were occurring in the debris bed at higher flow rates and that these would be expected to limit the increase in head loss as flow increased. The licensee also provided information, based on flow changes during the test, which showed the higher flow rates did not result in a non-linear increase in head loss as might occur due to bed compression. In addition, after the flow rates were increased and then reduced to the pre-increase value, the head loss fell below the previous value at the lower head loss. The licensee concluded that the effect of bore holes was greater than the effect from potential additional bed compression. The licensee stated that the flow changes near the end of the test were the basis for the extrapolation and that the extrapolation conservatively used a greater than 1:1 head loss-to-flow relationship. The licensee also stated that the head loss increases at higher flow rates were expected to be limited by bore holes. The NRC staff reviewed the licensee's response and performed a detailed review of the head loss information provided. The NRC staff also reviewed the NPSH margin available for the ANO-1 pumps that take suction from the containment sump. Based on industry test results, the NRC staff determined that it is unlikely that chemical precipitates would be present until late in the event when significant NPSH margin is available. Therefore, the concern is with the structural ability of the strainer to withstand differential pressure. The structural ability of the strainer to withstand differential pressure was calculated to be about 10.5 ft. of head, which compares favorably to the 8 ft. maximum head loss calculated by the licensee. Based on the head loss data provided, the licensee evaluation of the data, and the available margins for strainer head loss, the NRC staff is confident that the extrapolated head loss is an acceptable value for the ANO-1 plant conditions.

In its letter dated September 29, 2010, the licensee provided information regarding changes to the head loss testing evaluation for ANO-1. The licensee provided an updated table of debris loads for the limiting breaks that refined some of the predicted loads. All plant loads remain bounded by the test amounts. The submittal also provided the changes made to ZOIs and debris characteristics for fibrous debris and Cal-Sil, which are discussed in the debris generation section of this document. The submittal stated that a previously uncredited viscosity correction was applied to higher temperatures for calculating NPSH margins. Finally, the licensee stated that accident pressure is no longer required to prevent flashing across the strainer. The NRC staff reviewed these changes and found them to be consistent with guidance and acceptable.

ANO-2 Review

The licensee replaced the original sump strainer with passive CCI strainer modules with an area of 4,837 ft^2 to reduce head loss. The licensee also replaced the TSP buffer with NaTB to reduce the chemical precipitates that could form and transport to the strainer. The licensee removed some fibrous and Cal-Sil insulation and installed banding on some Cal-Sil to reduce the probability that it would become post-LOCA debris. The NRC staff witnessed some of ANO-2's integrated chemical effects head loss testing during a visit to Fauske Labs in August of 2007. The NRC staff found that the testing was generally conducted using procedures that would produce prototypical or conservative head loss values. The ANO-2 testing was conducted by Fauske Labs using procedures that reflected incorporation of NRC staff comments made during interactions with industry.

The amount of fibrous debris available to the strainer is relatively small, except for one break ZOI that contains significant amounts of fiber. This break also contains Cal-Sil, but in lesser quantities than other breaks that have no fibrous debris (except latent) associated with them. The potential for the formation of a filtering bed exists for all breaks because Cal-Sil is known to result in significant head losses with very little fibrous debris in the bed. Because of the large variation in debris types between breaks, the licensee tested the high fiber/Cal-Sil case separately from the limiting latent fiber/Cal-Sil case. Testing included 15 lb (scaled) of fibrous debris to represent the latent fibers. The licensee stated that actual sampling found that ANO-2 had 47 lb of latent debris. The licensee also stated that there is less than 100 ft^2 of miscellaneous debris in the containment. A sacrificial area of 200 ft^2 was included for test scaling purposes. The maximum flow through the strainer is about 7,065 gpm, unless a LPSI pump fails to trip, which would add about 5,700 gpm to the flow. Testing was conducted at a scaled flow including the LPSI flow at the start with a flow reduction to the design flow rate later in the test. The corresponding approach velocity is about 0.0059 ft/sec for the 12,765 gpm flow (including LPSI). The design (maximum allowable) head loss was stated to be at least 0.975 ft. for the early part of the event when no chemicals and no erosion debris were present (based on NPSH margin and a LPSI pump running), at least 1.75 ft. for a similar case with the LPSI pump secured (but including additional debris that would arise from erosion over 3 days), and at least 6 ft later in the event (based on strainer structural strength). The limit based on the margin to vortex formation is evaluated as 7.5 ft (strainer is vented).

The licensee calculated the CSHL value at 0.33 ft at the design flow rate of 7,065 gpm and 1.07 ft. if a LPSI pump fails to trip (12,765 gpm). The licensee stated that the CSHL was dominated by exit losses from the strainer modules into the plenum, while head loss through the strainer surface was negligible, which is consistent with the CSHL calculations for similar strainer installations.

Testing determined that the low fiber break with more Cal-Sil (S6) resulted in higher head loss than the high fiber break with lower amounts of Cal-Sil (S4).

The head losses for the tested conditions are as follows:

1. Cold Leg Break including LPSI flow (12,675 gpm) considered for first 30 minutes – 0.61 psi.

2. Cold Leg Break after LPSI secured with 3-day erosion (7,065 gpm) – 0.82 psi.

3. Cold Leg Break 7,065 gpm with chemicals and all eroded debris – 3.5 ft (1.4 psi).

All results are based on reduced debris loading that was accomplished by removing debris sources during the spring 2008 RFO.

The licensee noted that the strainer is fully submerged at the onset of recirculation during both small break and large break LOCAs. The analysis and testing for vortexing was completed using the minimum submergence value. The licensee included volumes from the safety injection tanks (SITs) in the minimum water level calculation. In addition, holdup in the refueling pool was accounted for only for large break LOCAs (LBLOCAs) that could create sufficient debris to block the lower refueling canal deep end drains. The minimum submergence including SIT volume was stated to be about 1 ft. The licensee also stated that without crediting the SIT volume and removing the LBLOCA holdup in the refueling canal deep end, the strainer would remain submerged.

The ANO-2 sump is vented to the atmosphere under anticipated operating conditions. The ANO-2 flashing evaluation did not credit accident pressure to assure that no flashing would occur during recirculation. Because the sump is vented, the pressures upstream and downstream of the strainer are equalized and flashing should not occur.

The licensee stated that during testing all fibrous debris was rendered into fines and very small pieces. In addition, fibrous debris was added in a manner to prevent agglomeration of the fines and small pieces. Based on this and observations of the NRC staff during its visit to Fauske Labs, the fibrous debris preparation and addition is considered to be acceptable. The amounts of debris that were assumed to be present in the plant were provided. The amounts of debris and the flow rates used in testing were scaled based on the ratio of the test strainer area to the plant strainer area.

The licensee stated that manual agitation was used to keep debris in suspension until it reached the strainer.

By letter dated May 21, 2009, the NRC staff issued RAIs B.11–B.14. By letter dated September 24, 2009, the licensee responded to the RAIs. The discussion below describes the RAIs and responses in more detail.

In RAI B.11, the NRC staff requested the licensee to provide additional information on the potential interactions between the emergency sump and the floor drains that empty into the sump. The NRC staff asked additional questions related to the floor drains. In its response, the licensee provided additional information on the configuration of the sump and the lines that communicate with it. The ANO-2 sump is vented and contains two box strainers that screen inputs from drain lines that enter the sump. These boxes are designed to prevent debris larger than 1/16-inch from entering the sump, consistent with the design of the sump strainer openings. Other lines that penetrate the sump are isolated with locked closed isolation valves during operation. The lines penetrating the sump are self-venting. The NRC staff reviewed the licensee's response and found it satisfactory.

In RAI B.12, the NRC staff requested the licensee to provide the methodology used for calculating the CSHL. In its response, the licensee stated that the CSHL was calculated using a combination of testing, CFD modelling, and standard hydraulic calculations. The testing was used to validate the calculated head loss for the strainer cartridges. CFD was used to determine the flow distribution between the branches of the strainer assembly. The standard hydraulic calculations were used to determine the head loss for the conduits connecting the strainer cartridges. The calculations included both clean and debris laden values for the non-debris portion of strainer head loss. The NRC staff reviewed the licensee's response and determined that the CSHL calculation was conducted using accepted methodologies and industry standard practices and was therefore acceptable.

In RAI B.13, the NRC staff requested the licensee to provide information regarding the sensitivity testing or other analyses showing that the addition of fibrous debris prior to other types of debris is conservative or at least neutral to the test results. In its response, the licensee stated that the head loss test program was designed to conservatively maximize strainer head loss regardless of whether the test condition was prototypical or not. The licensee also noted that the fibrous debris load for ANO-2 is very low. The licensee stated that debris was prepared into fine debris and steps were taken to prevent agglomeration during debris addition. The licensee also stated that the testing was conducted in a clear test flume so that the fibrous debris could be observed as it transported to the strainer and built a fiber bed. The licensee conducted several tests to determine how the strainer and potential debris load combinations behaved with respect to head loss. The licensee stated that the addition of particulate debris prior to the fibrous debris addition could result in agglomeration of the small amount of fiber available for transport to the strainer. The licensee conducted post-test examinations of the debris beds attained during testing. The debris beds were described as well-formed and evenly distributed. The NRC staff does not agree that the addition of particulate prior to the fibrous debris would result in agglomeration of the fibers. However, the NRC staff found that a relatively uniform bed was formed during the testing and that a conservative head loss value for ANO-2 was achieved based on the information discussed above. The NRC staff also concluded that the licensee conducted a rigorous test program, including over 20 tests to determine the limiting head loss for the plant. Therefore, the NRC staff found the response satisfactory.

In RAI B.14, the NRC staff noted that testing head loss values listed in Section 3.f.4, “Head Loss Testing,” of the licensee’s letter dated September 15, 2008, did not seem to correspond to the head loss values listed in the table of results section in the chemical effects section. The NRC staff requested the licensee to provide information explaining why the values were different. The licensee provided additional information regarding the test results and head loss limits for three scenarios of ECCS operation. The licensee conducted a time-dependent head loss evaluation. The three scenarios are for: (1) LPSI pump failure to trip at the time of the recirculation actuation signal, (2) two-train operation without chemicals, and (3) two-train operation with chemicals. The licensee provided the test debris loads, test results, and allowable head loss for each scenario. The tested head loss was less than the allowable with margin available for each case. The NRC staff reviewed the licensee’s response and noted that the response provided adequate clarification and details for the staff to understand why there were differences between the two tables. The response showed that the measured head loss values were less than the allowable head losses for each case. Therefore, the NRC staff found the response acceptable.

In its letter dated September 29, 2010, the licensee provided updates to some areas of the head loss evaluation. These updates were provided to include clarifications to the analysis and incorporate the information from RAI responses that had been submitted previously. The updated response provided clarity regarding the design-basis head losses and test results and discussed how the term “NPSH margin” is used in the licensee’s analysis. The response provided: (1) updated plant debris loads and strainer test amounts, (2) additional description of the procedures used during testing, (3) some adjustments to the margins and conservatisms that were included in the testing portion of the analysis, and (4) a description of the viscosity scaling applied to the test results for use at high sump temperatures.

<u>NRC Staff Conclusion</u>

For the head loss and vortexing area, the licensee provided information such that the NRC staff has reasonable assurance that the strainer head loss and potential for air ingestion has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the head loss and vortexing evaluation for ANO 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 CSS pumps that would exist during a LOCA, considering a spectrum of break sizes.

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through September 29, 2010.

The licensee provided the information specified in the content guide (identified in Section 1.0 of this document). The methodology used to calculate NPSH margin is a standard industry practice that uses a combination of realistic and conservative assumptions.

ANO-1 Review

The ANO-1 ECCS and reactor building spray (RBS) system each include two trains of pumps. Each ECCS train consists of one HPI pump and one LPI pump. Each RBS train has one pump. On actuation of the safety injection signal (start of the injection phase), the HPI pumps automatically realign suction from the makeup tank to the borated water storage tank (BWST), and the LPI pumps start with suction from the BWST discharging through the decay heat removal coolers. These pumps, along with the two CFTs, discharge into their respective reactor vessel core flood nozzles. An RBS actuation signal or manual actuation starts the RBS pumps, which take suction from the BWST and discharge to the spray headers. Operators throttle the RBS pump flow rates to about 1,000 gpm each.

When the BWST level drops below 6 ft indicated level, operators initiate entry to the recirculation phase by turning off the HPI pumps, manually throttling the RBS pump flow, and shifting the LPI and RBS pumps' suction from the BWST to the containment recirculation sump. (Note that in the case of a SBLOCA, where reactor pressure remains above the LPI pump discharge pressure, an alternate pump alignment would be used. In this scenario, the HPI pump suction would be shifted to the LPI pump discharge for piggy-back or booster pump operation).

The licensee stated that the LPI pump maximum net flow rates are 3,547 gpm, and the RBS pump flow rates are 1,320 gpm. The maximum total two-train operation sump flow rate is therefore 9,734 gpm. The minimum reactor building water level for recirculation was identified as greater than 4.9 ft. The minimum strainer surface submergence is greater than 7 inches. The maximum sump temperature is 259 ° Fahrenheit (F) at about 66 minutes post-LOCA (when recirculation starts) and trends down to below 208 °F at about 22 hours post-LOCA.

The licensee stated that the NPSH-required values were based on the vendor-certified pump curves. Since the vendor technical documents for this unit do not specify otherwise, the NRC staff considered it reasonable to assume the industry standard practice criterion of 3 percent reduction in head loss. Containment accident pressure is assumed not to contribute to NPSH-available. This is a conservative assumption for the partial pressure of air in containment prior to the LOCA.

The licensee showed the following minimum pump NPSH margins. These values include the CSHL but do not include the debris blockage or chemical effects head losses.

- A Train LPI Pump > 5.0 ft
- B Train LPI Pump > 4.5 ft
- A Train RBS Pump > 5.5 ft
- B Train RBS Pump > 4.0 ft

The assumptions for minimum sump water level include:

- Design minimum of borated water injected (conservative low CFT mass used, zero transfer from makeup tank, BWST at lowest allowed level/mass).
- Holdup in the refueling canal.
- Increase in containment atmosphere water vapor content maximized.
- Minimum contribution from the spray additive tank.
- Maximum amount of spray water in fall transient in containment.
- Spray piping starts empty downstream of the pump discharge motor-operated valves.
- One-eighth inch water film on total vertical and horizontal surface area of 350,000 ft^{2}.
- Only substantial structures displace water in the containment pool.
- No loss of RCS liquid mass (other than CFTs), RCS volume acquires additional mass from injected water as the contents cool and become more dense.

The minimum sump water level was calculated to be 4.9 ft.

In its letter dated September 29, 2010, the licensee stated that the systems being evaluated are designed to perform their safety functions assuming a single active failure. The licensee also clarified that for the condition where the sump temperature is above saturation at the minimum allowable containment pressure, the reactor building pressure is assumed to be the vapor pressure for the corresponding temperature for the analyses. The response also provided finalized NPSH margins that include clean strainer margins and debris-laden margins for the LPI and RBS pumps. These margins account for extrapolation of the test values to higher sump temperatures due to decreased fluid viscosity.

<u>ANO-2 Review</u>

The licensee provided the ECCS and CSS responses following a LOCA. For a LBLOCA, the LPSI and high-pressure safety injection (HPSI) pumps start taking suction from the refueling water tank (RWT). The CSS pumps start, also taking suction from the RWT if containment pressure reaches 23.3 psi absolute. When the RWT reaches the low level set point, the HPSI pumps are swapped to recirculation from the containment sump. When the RWT reaches the low level setpoint, the LPSI injection is automatically stopped. The CSS pumps also swap to recirculation at the RWT low level setpoint.

The licensee provided pump maximum flow rates and sump flow rates for various post-LOCA conditions, including the potential for a single failure where the LPSI pump fails to trip resulting in higher flow through the strainer.

The licensee stated that the minimum sump level is 7 ft above the basement floor. For the sump level analysis, the licensee assumed the following:

- For a LOCA, the break was assumed to be on the top of the reactor such that RCS contribution to containment flood volume was zero.
- Boric Acid Makeup Tank (BAMT) volume was assumed to be zero.
- RWT level was assumed to be the minimum technical specification (TS)-allowable at the maximum allowable temperature.
- SIT volume was set equal to the TS minimum value.
- Volume of water in air was maximized [droplets in transit].
- Maximum mass of water vapor was used.
- Wetted surfaces were assumed maximum [1/8-inch film on 200,000 ft^2].

Large structures were assumed to displace water and increase the sump level. The licensee credited RWT and SIT inventory in the water level analysis. However, for the LBLOCA case that could result in holdup in the refueling canal, the licensee credited RCS volume to offset the holdup.

The sump fluid temperature was based on the temperature expected from 2,000 seconds until well after the initiation of the event. The license reported that the maximum sump temperature at 2,000 seconds is 224 °F.

The licensee stated that the most conservative manufacturer’s HPSI pump NPSH required (NPSHR) curve was used to determine the required NPSH for all of the pumps. The manufacturer’s pump information did not provide the basis for the curves.

The licensee stated that the ECCS and CSS piping friction losses were calculated using a temperature dependent analysis because piping losses change with temperature.

The licensee stated that containment accident pressure was not credited in the NPSH calculations. For sump temperatures above the saturation temperature, the licensee assumed that the pressure was equal to the vapor pressure of water at that temperature. For lower temperatures, the licensee credited subcooling of the liquid.

The licensee provided NPSH margins (excluding debris losses) for various pump combinations and for various times (temperatures) after the initiation of the LOCA. The licensee stated that the limiting HPSI pump NPSH margin (without debris losses included) ranged from 1.8 ft at 220 °F to 16.8 ft at 176 °F.

The licensee's letter dated September 29, 2010, stated that time dependent debris transport is no longer credited, as discussed in the transport section of this staff summary. The licensee's calculation assumes that a LPSI pump that had failed to trip would be secured before chemical effects can impact head loss.

The update also provided revised NPSH margins for the pumps, including viscosity corrections that were discussed in the head loss section of this document. The update also provided the limiting margins, including debris losses. The HPSI pumps maintain greater than 1.5 ft of margin, except for the case where the "C" HPSI pump is aligned to the "A" train and taking suction from the sump with a LPSI pump that has failed to trip. In that case the margin is 0.75 ft of head. The CSS pumps maintain considerably higher margins.

NRC Staff Conclusion

For the NPSH area, the licensee provided information such that the NRC staff has reasonable assurance that it has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the NPSH evaluation for ANO 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 September 29, 2010.

The original coatings ZOIs were assumed to be 4D for qualified epoxy coatings and 5D for qualified untopcoated inorganic zinc (IOZ) based on testing and WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings" (ADAMS Accession No. ML061990594; not publicly available, proprietary information). Coatings in the ZOI were assumed to fail as fine particulate. All unqualified coatings in containment were assumed to fail as fine particulate. The debris transport analysis assumed that 100 percent of the coating debris would transport to the sump.

The licensee later revised its coating ZOI assumptions based on a change to the NRC guidance that determined that untopcoated IOZ should be assumed to have a ZOI of 10D instead of the 5D that was originally assumed. The NRC staff guidance that allowed the larger ZOI was transmitted to NEI by letter dated April 6, 2010 (ADAMS Accession No. ML100960495). In its letter dated April 8, 2010, updating the supplemental response, the licensee committed to perform walkdowns in both units to identify areas in the SG cavities coated only with IOZ. These areas were the only areas identified as potentially being affected. The results of the walkdowns are to be used to determine the increase in untopcoated IOZ debris generation and verify that the analysis contained adequate coatings debris to bound the plant condition. In its revised response dated September 29, 2010, the licensee reiterated the change for untopcoated IOZ from a ZOI of 5D to 10D. The NRC staff conducted a teleconference with the licensee to determine whether the actions were complete. The licensee verified it had performed the walkdowns and that the coating amounts in the analysis bound the plant condition.

The licensee observed a thin bed during testing and treated all of the generated coatings debris as fine particulate. In addition to the fine particulate coatings debris used in testing, paint chips were also added to the testing debris, equivalent to 1 ft^3 of paint chips in the reactor building that was scaled to flume test size. This was done as a conservative measure for margin that could be credited in the future.

The NRC staff determined that the surrogate material used for testing is acceptable. The NRC staff also determined that the licensee's coating assessment program met expectations.

NRC Staff Conclusion

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

11.0 DEBRIS SOURCE TERM

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

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through September 24, 2009.

The licensee, as part of the reactor building walkdowns used to identify potential debris sources, took measurements to conservatively determine the amount of latent dirt and dust inside of the reactor building. These measurements were taken at a point during an RFO, where the level of dirt and dust was much higher than during normal power operation. Extensive cleaning was performed subsequent to the measurements being taken, but prior to unit startup. These cleaning activities are consistent with normal housekeeping practices and associated administrative requirements. The NRC staff concluded that the licensee has an adequate reactor building cleanliness procedure.

In its letter dated August 31, 2005, the licensee committed to measuring latent debris quantities every third RFO to confirm that latent debris quantities used in strainer testing and downstream effects analysis remain bounding. As noted in that letter, the plant may choose to relax this frequency after the first measurements, provided that the results indicate that an adequate level of cleanliness was maintained. The results of the initial two inspections will be compared to the margins available for latent debris and, provided adequate margin remains, the inspection frequency and scope may be relaxed. The sample scope may be reduced to two samples of each of the representative surface types and the frequency extended from every third outage to every fourth outage. If subsequent inspections reveal that housekeeping and cleanliness measures continue to maintain latent debris loading below the tested/evaluated values with sufficient margin, then the inspection frequency could be extended to a maximum interval of every sixth outage (not to exceed 10 years). If inspection results reveal an adverse trend in latent debris quantities such that latent debris margin for the tested and analyzed conditions are unacceptably reduced, then the inspection frequency will be shortened and the scope increased, as appropriate, to ensure adequate margin is maintained.

Both the strainer qualification tests, and the downstream effects analysis included fiber and particulate quantities greater than the measured values for latent debris to ensure that substantial margin exists to bound possible future increases in latent debris.

The licensee has in place maintenance housekeeping procedures to control materials used within the reactor building. These procedures act to minimize the creation of foreign materials. A reactor building closeout procedure is in place to inspect the reactor building following RFOs to ensure that foreign materials are not present (including in the sump). The NRC staff confirmed that the licensee has an adequate foreign material exclusion procedure.

The licensee's procedure for control of design modifications includes a list of design input considerations concerning potential debris sources. This list includes specific items that address insulation and coatings in the reactor building to ensure modifications that may affect sump performance are evaluated.

Maintenance activities are planned, scheduled, and implemented within the bounds of the regulations in 10 CFR 50.65, "Requirements for monitoring the effectiveness of maintenance at nuclear power plants." Maintenance involving insulation or coatings is performed in accordance with engineering-approved specifications. Temporary modifications are controlled using the same design input considerations as permanent modifications.

For ANO-1, during RFO 1R19 (fall 2005), problematic insulation types in the SG cavities were removed during the SG replacement project. Fiber and Cal-Sil insulation were removed from the RCS, feedwater, and main steam piping in the SG cavities and replaced with RMI. This effort removed a significant amount of the problematic material types from the SG cavities. The licensee took additional actions in the 1R20 RFO (spring 2007) by replacing additional sections of Thermal Wrap fibrous insulation with RMI and removing unnecessary fibrous insulation from piping. The licensee modified existing insulation systems during RFO 1R20. This consisted of the addition of banding to Cal-Sil insulation lagging (original lagging fastened with sheet metal screws) to reduce the ZOI to 5.45D, which is consistent with NRC staff guidance.

For ANO-2, in RFO 2R19, the licensee replaced fibrous and Cal-Sil insulation with RMI during SG replacement. During the same outage, banding was added to reduce the ZOI associated with remaining Cal-Sil insulation. The insulation system was modified to be consistent with the system that has an assumed ZOI of 5.45D, as approved in NRC staff guidance.

A site procedure controls licensee commitments related to its safety-related coatings program at ANO, Units 1 and 2. This procedure provides the minimum requirements at ANO, Units 1 and 2, to ensure that coatings are properly selected, applied, and maintained so the coatings can perform their intended function without negatively impacting the safety functions of other structures, systems, and components. This procedure addresses the activities related to service-level I coatings inside the reactor building, where coating failures could adversely affect the operation of the post-accident fluid systems and thereby impair safe shutdown of the units.

By letter dated May 21, 2009, the NRC staff issued RAIs A.10 for ANO-1 and B.15 for ANO-2. The NRC staff requested the specific procedures mentioned in the debris source term for control and maintenance of containment cleanliness. By letter dated September 24, 2009, the licensee responded to the RAIs.

For ANO, Units 1 and 2, the licensee stated that the general control of area cleanliness for the site is addressed in Procedure 1000.018, "Housekeeping." In addition to the housekeeping procedure, Procedure 1015.036, "Containment Building Closeout," includes specific guidance regarding inspections of the sump screens and areas within the reactor building prior to plant heatup and again prior to reactor building closeout. The inspections performed per Procedure 1015.036 involve multi-discipline teams that address detailed checklist inspections of the sump strainers as well as accessible areas of the reactor building. Instructions are provided to address a wide variety of potential sources of debris or foreign material, as well as the storage of materials inside the reactor building.

The NRC staff found that the procedures in place at ANO, Units 1 and 2, to control the debris source term quantities under the limits assumed, are acceptable. This conclusion was based on the description provided by the licensee regarding how these procedures will control and maintain the cleanliness of the containment. Because ANO, Units 1 and 2, contain small amounts of fibrous insulation and there are a number of uncertainties associated with the values assumed for latent debris, the licensee has implemented an ongoing latent debris program to periodically verify that the latent debris quantities are within those assumed in the analyses.

NRC Staff Conclusion

For this review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris source term evaluation for ANO 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 September 24, 2009.

ANO-1 Review

The sump screen design modification removed the original sump screen, vortex eliminator, carbon steel divider plate, and concrete curb with scuppers. The original screen was replaced with a new CCI strainer assembly consisting of modular screen cartridges with perforated 1/16-inch holes. The screen fits over the sump and has a footprint that is slightly larger than the nominal dimensions of the sump. The new replacement strainer has a surface area of approximately 2,715 ft^2, compared to the original screen area of approximately 200 ft^2.

The licensee stated that the stainless steel materials for the new components are more resistant to corrosion than the original carbon steel materials and provide improved performance with lower maintenance. The bottom of the strainer floor plate is approximately 1 inch higher than the reactor building floor. A stainless steel divider plate, similar to the original divider plate, was installed inside the strainer. The divider plate has a stainless steel screened mesh opening between the two sump halves consisting of 0.132 inch (nominal) square openings. The new sump strainer assembly and divider plate (including the integral screen) was fabricated from stainless steel to preclude corrosion and eliminate the need for protective coatings. The original vortex eliminator was removed and not replaced.

In order to lower the profile of the strainer so that it remains well below the water level, the original concrete curb surrounding the sump was removed. This curb contained scuppers so that water around the edges of the sump could flow into the sump. When the curb was removed to keep the new strainer as low as possible, the scuppers were removed with it. To prevent "ponding" due to the new strainer edge thickness (i.e., less than 2 inches), new drains with integral filters were bored to allow water around the edge of the sump to flow into the sump.

ANO-2 Review

The original sump screen was replaced with a new CCI modular strainer system. The new replacement strainer has a surface area of 4,837 ft^2, compared to the original screen area of approximately 154 ft^2. Two banks of new strainer modules extend from the east and west sides of the sump. The east side consists of fourteen screen modules and the west side consists of eight screen modules. The strainer pockets are made of perforated stainless steel plates. The pocket design leads to favorable conditions for the water flow; the water passes through the volume of each cavity in five directions. This shortens the water flow path through the debris bed and minimizes the penetrating velocities and the associated head loss.

The strainer openings are 1/16-inch diameter holes. The screens connect to a new plenum installed over the sump. The new sump plenum and its internal divider plate and screen were fabricated from stainless steel to preclude corrosion and eliminate the need for protective coatings. The screen openings for the divider are 0.132 square inches. Screened openings at the bottom of the plenum walls were provided to allow water on the containment floor to enter the sump for leakage detection purposes, while excluding debris greater than 1/16-inch in size. The plenum incorporates two pipe vents on the top surface. The purposes of the vents are to allow air contained inside the plenum to escape as the plenum fills with water and to limit internal pressurization due to pressure transmitted through the floor drains entering the sump. The vents extend above the high containment water level and are provided with 12 x 12 mesh (with 0.047-inch diameter wire) woven screens to prevent debris entry. Two track-mounted, sliding doors are provided for personnel access to each side of the sump. Two box screens are mounted inside the sump on the northeast and northwest walls to capture debris entering the sumps via floor drains that bypass the containment sump screen. The original box screens were replaced with stainless steel mesh (i.e., 0.047-inch diameter wire) to prevent the introduction of particles greater than 1/16-inch through the floor drains. In addition, several miscellaneous pieces of equipment were relocated to accommodate the area for the new strainer.

RAI Review

By letter dated May 21, 2009, the NRC staff issued RAIs A.12 for ANO-1 and B.18 for ANO-2. The NRC staff requested the licensee to provide the technical basis for concluding that blockage would not occur in the stainless steel divider plates that separate the ECCS sump into two halves. By letter dated September 24, 2009, the licensee responded to the RAIs. In its response, the licensee cited the following conditions for concluding that formation of a fibrous debris bed on the divider plate that is capable of filtering particulate is not a credible event:

- the area of each square openings in the divider-plate is 5-times greater than the area of a perforation in the strainer.
- the quantity of fiber available for transport to the sump divider plate is small.
- the conservatism in the debris generation and transport calculations provide margin.
- the strainer-bypass fraction is low.
- the assumed divider-plate fiber capture efficiency is 34 percent.
- the normal flow rate across the divider-plate is low.

The licensee also stated that the divider plate enhanced safety by adding a barrier against a common mode failure mechanism associated with a single sump pit providing a suction source for both trains of ECCS and CSS. The NRC staff reviewed the licensee's response and found it acceptable. The NRC staff based this finding on the small quantity of fiber available for capture by the divider plate and the fraction of the flow passing through the divider plate, as reported by the licensee. In addition, the NRC staff noted that the capture fraction of 34 percent for the divider plate is likely very conservative, such that less fiber than predicted by the licensee would collect on the divider plate. Considering the very low probability that it would provide significant head loss, the NRC staff finds that there is reasonable assurance that the strainer will perform its intended function as required.

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 ANO 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 review is based on documentation provided by the licensee through September 24, 2009.

The licensee stated that a structural analysis was performed for the replacement sump strainers. The models analyzed the structural integrity of the strainers when subjected to load combinations associated with dead load, debris loads, differential pressure loads, seismic loads, hydrodynamic loads (sloshing), and temporary loads (e.g., lead shielding during outages). The application of these individual loads is consistent with the guidance of NEI 04-07 and the NRC staff's corresponding SE. The maximum stresses, which were calculated in the analytical models, were then compared with the appropriate allowable stresses from the American Institute of Steel Construction (AISC) Manual (AISC 9th Edition for ANO-1 and AISC 7th Edition for ANO-2). Also, the licensee stated that the concrete anchorage bolts were designed in accordance with a site-specific ANO design guide.

The licensee stated that the replacement sump strainer was not subjected to any jet impact or pipe whip effects associated with a potential HELB. The licensee also stated that backflushing was not credited.

By letter dated May 21, 2009, the NRC staff issued RAIs for this area (A.13–14 for ANO-1 and B.19–20 for ANO-2). In RAIs A.13 and B.19, the NRC staff requested the licensee to provide a summary of structural qualification design margins for the various components of the sump strainer structural assembly, including interaction ratios and/or design margins for structural members, welds, concrete anchorages, and connection bolts, as applicable. In RAIs A.14 and B.20, the NRC staff requested the licensee to provide additional justification for the HELB evaluation (evaluations performed for dynamic effects such as pipe whip and jet impingement associated with HELBs as they relate to the structural integrity of the replacement sump strainers).

By letter dated September 24, 2009, the licensee responded to the RAIs. In its response to RAIs A.13 and B.19, the licensee provided the requested summation of the structural analyses results performed for the structural qualification of the replacement strainer structures. This summation included details regarding the interaction ratios for all of the elements making up the strainer structure including structural members, welds, concrete anchorages, and connection bolts. In its response to RAIs A.14 and B.20, the licensee described its theory and approach for justifying that neglecting dynamic effects of HELBs was appropriate, with respect to the structural integrity of the replacement strainer. This justification was supported by the licensee's conclusion that the HELB lines considered in the evaluation did not pose a threat due to either (1) their distance from the strainers, (2) a break in the line would not requiring sump recirculation to safely shutdown the plant, or (3) adequate shielding was provided by a wall or other structure. The NRC staff reviewed the licensee's responses to the RAIs and found them acceptable.

NRC Staff Conclusion

For this review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the sump structural analysis evaluation for ANO 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 September 24, 2009.

ANO-1 Review

The licensee described the location of the sump pit and the potential flow paths for debris and water migrating toward the sump. Spray washdown would fall through gratings to the basement from the areas inside and outside the SG compartments. Spray flow falling into the refueling canal region would drain through a 6-inch drain into the reactor cavity and incore tunnel and would flow out through a locked open hatch into the basement. The licensee evaluated the refueling canal reactor cavity drainage paths and determined that no potential for debris blockage exists. Additionally, the licensee took no credit for flow through normal floor drains; therefore, no measures are necessary to mitigate potential choke points for these drains. There are no curbs or debris interceptors installed. Therefore, no water holdup analysis for these structures is necessary.

The licensee evaluated the refueling canal drainage path for potential debris blockage. No holdup was assumed for the reactor cavity, as it is drained through a large open manway.

The licensee stated that characteristics of the post -LOCA debris will not obstruct drainage of inventory from the refueling canal. The licensee concluded that drainage flow in the canal cannot transport large and small debris, which would remain on the refueling canal floor. Fines and floating debris are assumed to pass through the drain without obstructing or plugging it. The licensee determined that although large debris may migrate to the incore instrumentation tunnel access hatch opening during pool fill, it will not be lifted up and block the hatch.

The licensee assumed a maximum of approximately 11,000 gallons of inventory is retained in the refueling canal based on the spray flow into the volume and the head required to maintain flow through the drain line. The refueling canal drain is configured to draw water from above the refueling deep end floor.

By letter dated May 21, 2009, the NRC staff issued RAI A.11, requesting the licensee to provide additional information to justify the licensee's assertion that the refueling canal would not become blocked with debris.

By letter dated September 24, 2009, the licensee responded that a risk-based approach was used to qualify the refueling canal drain capability with respect to blockage rather than attempting to quantify the debris deposited into the refueling canal. The licensee stated that the drain line is centered horizontally 9 inches above the bottom of the refueling canal. Part of the RBS flow rate would fall into the refueling canal. The holdup of about 3.5 ft was credited to provide head to drive the water through the drain line. Small quantities of floating debris could be drawn into the drain. The licensee stated that the floating debris would likely be fines and light debris, which would not block the drainage path.

The licensee described the paths for large debris that could be blown into the refueling canal. The licensee stated that the most likely path for debris to reach upper containment is through the SG cavity upper opening. The licensee also stated that small debris and fines are assumed to accumulate on the refueling canal floor and on equipment and structural surfaces in the reactor building.

The licensee stated that large debris was likely to be obstructed from transporting to the refueling canal by structures, gratings, and system components. The licensee stated that the SG cavity upper elevation is completely grated except for openings for ladder access so that it is unlikely for large pieces of debris to be ejected through these openings.

The NRC staff reviewed the response and found that the holdup volume in the refueling cavity has been properly analyzed by the licensee and that it is not credible that debris would block the refueling canal drain line. The NRC staff found that there is a low probability of debris large enough to block the drain reaching the refueling cavity and being transported to the drains.

ANO-2 Review

The licensee described the flow paths from the postulated breaks and sprays to the sump strainer. The licensee evaluated the refueling canal reactor cavity drainage paths for potential debris blockage. The licensee stated that spray flow falls into the refueling canal and drains to the basement through one of the two 8-inch drain lines, one for each deep end of the canal. Each of the drain lines has a drain cover, which was enlarged to help prevent it from becoming clogged with debris.

The licensee stated that the reactor cavity drains through a 10-inch drain line with a check valve to prevent backflow into the cavity. The check valve had a screen that was removed so that no choke points exist in this drain path. There are no curbs on the containment floor and no credit has been taken for floor drains. Therefore, these features are not evaluated by the licensee.

The licensee determined the refueling canal drain flow rate based on CSS flow rates and the ratio of the refueling canal area to the full containment area. The head loss for the refueling canal drains was determined using standard hydraulic analysis methods for the maximum postulated drain flow rate. The water holdup in the refueling canal was calculated to be 4,310 gallons in the east deep end and 2,270 gallons in the west deep end.

By letter dated May 21, 2009, the NRC staff issued RAIs B.16 and B.17. By letter dated September 24, 2009, the licensee provided responses to the RAIs.

In RAI B.16, the NRC staff requested the licensee to provide a description of the refueling canal drain cover and the basis for concluding that the refueling canal drain would not become blocked by post-LOCA debris.

In its response, the licensee provided details of the design of the drain covers, including a sketch that showed the important details of the design. The licensee stated that the design will allow water flow while avoiding the risk of blockage.

The licensee stated that, for most breaks, only debris that can fit through grating openings could credibly arrive at the refueling canal. Alternately, a break in the surge line below the pressurizer could produce larger debris with the potential to contribute to blockage of the refueling canal drains, but this break would likely have a downward trajectory because the floor slab below the pressurizer is a robust barrier that blocks debris from being ejected upward.

The NRC staff reviewed the response and found that blockage of the refueling cavity drains is highly unlikely. This conclusion was based on debris types that could potentially reach the canal and the design of the refueling canal deep end drain strainers. Complete blockage of the drains is not considered credible, and partial obstruction, while considered highly improbable is shown to be acceptable based on the assumed holdup inventory discussed in response to RAI B.17 discussed below.

In RAI B.17, the NRC staff requested justification for the sources and holdup volumes that are predicted to affect water inventory to the post-LOCA sump for the limiting cases. The minimum water level included inventory form the SITs, and it was not clear to NRC staff that the SITs would be available for all breaks that require recirculation.

In its response, the licensee stated that the minimum water level analysis credits the SIT inventory because small breaks that would limit the depressurization rate of the RCS would generate significantly less debris than the design-basis load tested during strainer qualification. The licensee stated that breaks as small as 0.05 ft^2 result in SIT inventory release to the RCS. Strainer tests demonstrated that strainer head loss will remain very low at the debris amounts that may be generated by these small breaks. The licensee stated that the SIT inventory is approximately 10 percent of the total sump inventory and that the water level would be approximately at the top of the strainers if the SIT inventory is not included.

The licensee calculated the refueling canal water holdup to be 6,600 gallons, or less than 2 percent of the sump water inventory. The licensee stated that holdup would only occur for breaks that generate significant amounts of debris. As discussed above in RAI B.16, the refueling canal drain covers were enlarged to prevent the potential for blockage. The response to that RAI also discussed the tortuous path that debris would have to take to reach the refueling canal. The NRC accepted that the drains in the refueling canal would not credibly become fully blocked. For small breaks, with small debris generation amounts, no blockage was assumed.

The licensee also stated that for small breaks, where the SITs do not discharge, the flow rates for ECCS pumps would be lower, leading to increased NPSH margins from both reduced friction losses at the strainer and in the suction piping, and reduced NPSHR for the pumps.

In its supplemental letter dated September 29, 2010, the licensee stated that the response to RAI B.16 regarding refueling canal drain blockage remains valid even though some of the debris generation assumptions regarding fibrous materials were revised. The response is valid for hot leg breaks because the tortuous path from the debris generation locations to the refueling canal prevents large debris from transporting. For cold leg breaks, there is not a credible source of large fibrous debris. Therefore, the assumption that the refueling canal drains are a viable flow path to the sump remains valid. The NRC staff found that the updated information is valid. The NRC staff reviewed the licensee's response and found that the reported minimum water level is applicable to all cases where strainer operation is required based on the rationale that breaks that do not require SIT discharge will not require ECCS recirculation. In addition, for small breaks where SITs do not discharge, the licensee has demonstrated that there is more than enough available sump level, even without the SIT inventory.

NRC Staff Conclusion

For this review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the upstream effects evaluation for ANO 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 CSS in terms of potential wear of components and blockage of flow streams.

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through September 15, 2008.

ANO-1 Review

The licensee stated that it performed a comprehensive downstream effects evaluation using the approved methodology in WCAP-16406-P and the associated NRC SE. The analysis evaluated components for blockage and wear in the affected systems. All components were found to have acceptable performance. The comprehensive analysis addressed the impacts of wear on spray nozzles, orifices, heat exchanger tubes, throttled valves, and the LPI and RBS pumps. Wear analysis of the HPI pumps was performed by the pump vendor, Flowserve Corporation. The licensee's analysis also considered the potential for blockage due to any small clearances in the system. The licensee stated that the debris loading for the downstream effects analysis used bounding inputs that exceeded the fiber and particulate loading determined by the debris generation calculation for the limiting break. The analysis used a strainer bypass value for fiber such that 5 percent was assumed to remain in circulation throughout the timeframe of the analysis. The licensee assumed 97 percent particulate amount downstream of the strainer. The licensee provided a summary of the evaluation conclusions as stated below:

- The calculated wear on the LPI and RBS pumps' wear rings would result in minimal head loss at the end of the mission time (i.e., 30 days).
- The decay heat cooler tubing has sufficient thickness to withstand erosion.
- The effect on system flow orifices was less than a 3 [percent] change in flow.
- The effect on spray nozzles was less than the 10 [percent] change in flow rate acceptance criteria.
- The effect on throttle valves was less than a 3 [percent] change in flow.
- There was no impact on control instrumentation and root isolation valves due to debris.
- Relief valves in the ECCS systems would not be prevented from performing their design functions due to debris in the water. The relief valves cannot reach their lift set points during the recirculation mode of operation.

The licensee stated that the cyclone separator and mechanical seal evaluation for the LPI, HPI, and RBS pumps consisted of an analysis based on plant-specific debris loads, cyclone separator flow rates, and geometric design parameters. The evaluation compared the plant conditions to a Wyle Laboratories testing program that evaluated these components. This analysis concluded that the cyclone separators would continue to function throughout the required response period. Since the licensee found that the cyclone separators would continue functioning to remove debris from the fluid, the mechanical seals were also determined to be qualified for the post-LOCA period. The licensee stated that the debris comparison for cyclone separator operation conservatively used debris loads that were conservative for the plant. The debris concentration passing through the sump strainer was conservatively assumed to be 5 percent of the total fiber and 100 percent of the particulate. The total assumed plant debris concentration remained significantly below the tested debris concentration for the cyclone separator tests. Thus, the cyclone separator test provides a significantly bounding condition relative to those applicable to ANO-1.

The licensee stated that the HPI pump is the only pump that injects in response to SBLOCAs, where the RCS pressure remains greater than the LPI pump injection pressure. The HPI pump is supplied by the LPI pump in “piggy back” mode of operation. The licensee stated that the HPI pumps were therefore evaluated for downstream effects. The licensee stated that because a debris generation analysis for SBLOCA conditions was not performed, the HPI pump wear analysis used the surge line break debris loading. The analysis assumes that 5 percent of the total fiber mass and 100 percent of the particulate mass passes through the sump strainer. A depletion coefficient was applied to the unqualified coatings debris outside the ZOI and all fibrous debris with the remaining debris was assumed to remain entrained in the recirculated fluid. The wear to pump internals was evaluated for a mission time of 30 days and found to be acceptable.

<u>ANO-2 Review</u>

The licensee stated that it performed a comprehensive downstream effects evaluation using the approved methodology in WCAP-16406-P and the associated NRC SE. The analysis evaluated components for blockage and wear in the affected systems. All components were found to have acceptable performance. The comprehensive analysis addressed the impacts of wear on spray nozzles, orifices, heat exchanger tubes, throttled valves, and HPSI and CSS pumps. Wear analysis of the pump seal and cyclone separators were evaluated by comparing their operating conditions to the Wyle Laboratories testing program. The licensee’s analysis also considered the potential for blockage due to any small clearances in the system. The licensee stated that the debris loading for the downstream effects analysis used bounding inputs that exceeded the fiber and particulate loading determined by the debris generation calculation for the limiting break. The analysis used a strainer bypass value such that 5 percent of fiber was assumed to remain in circulation throughout the timeframe of the analysis. The quantity of particulate downstream of the strainer was assumed to be 94 percent. The licensee provided a summary of the evaluation conclusions as stated below:

- The calculated wear on the HPSI and CSS pumps’ wear rings results in acceptable head loss at the end of the mission time (30 days) [Note that the LPSI pumps are not required during the sump recirculation phase of LTCC].

- The effect on system flow orifices was less than a 3 [percent] change in flow.

- The effect on spray nozzles was less than the 10 [percent] change in flow rate acceptance criteria.

- The effect on throttle valves was less than a 3 [percent] change in flow.

- There was no impact on control instrumentation and root isolation valves due to debris.

- Relief valves in the ECCS systems would not be prevented from performing their design functions due to debris in the water. [The pressure in the system does not reach the relief valves'] set points during the recirculation mode of operation.

The licensee stated that the cyclone separator and mechanical seal evaluation for the CSS pumps consisted of an analysis based on plant-specific debris loads, cyclone separator flow rates, and geometric design parameters. The evaluation compared the plant conditions to a Wyle Laboratories testing program that evaluated these components. This analysis concluded that the cyclone separators would continue to function throughout the required response period. Since the licensee found that the cyclone separators would continue functioning to remove debris from the fluid, the mechanical seals were also determined to be qualified for the post-LOCA period. The licensee stated that the debris comparison for cyclone separator operation conservatively used debris loads that were conservative for the plant. The debris concentration passing through the sump strainer was conservatively taken as 5 percent of the total fiber and 100 percent of the particulate. The total assumed plant debris concentration remained significantly below the tested debris concentration for the cyclone separator tests. Thus, the cyclone separator test provides a significantly bounding condition relative to those applicable to ANO-2.

The licensee stated that the HPSI pump mechanical seal evaluation concluded that the seals would perform their design function in the post-LOCA environment and that the HPSI pump seals are provided makeup water from the pump process fluid. The licensee further stated that the flow of water between the seal cavity and the process fluid is minimal because only fluid lost out of the seal requires makeup. Therefore, minimal debris would transport to the seal faces. The licensee assumed that seal coolers are in service. However, the HPSI pumps have been demonstrated to be operable without the coolers in service. Additionally, the licensee stated that tests conducted by the seal manufacturer (Durametallic) demonstrated satisfactory seal performance well beyond the 30-day mission time with seal water temperatures that bound the maximum sump temperature.

NRC Staff Conclusion

For the ex-vessel downstream effects review area, the licensee provided sufficient information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the licensee's evaluation of this area for ANO 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 October 4, 2021.

In its letter dated May 16, 2013, describing its closure options for ANO, the licensee stated that it needed to perform strainer penetration testing to determine accurate amounts of fiber that may pass downstream of the strainer because previous testing did not meet updated guidance for such testing. In that letter, the licensee stated that it would perform the testing and follow the PWROG resolution strategy for establishing in-vessel debris limits.

In its final supplemental response dated December 10, 2020, the licensee stated that its evaluation of in-vessel effects had been completed. Both units' responses referred to the NRC staff review guidance for IVDE (ADAMS Accession No. ML19228A011) for its evaluation of this area.

The licensee performed strainer penetration testing to quantify the amount of fiber that may pass downstream of the strainer and the reactor core. The penetration testing was representative of the most conservative conditions for ANO-1 and ANO-2. The testing was designed to bound the potential penetration for both units. The licensee performed two tests and used the results of Test 2, which provided a slightly greater penetration values than Test 1. The licensee described the test facility and test conditions in its final response.

Based on the licensee's submittal, the testing used full flow filtering to ensure that all fiber that penetrated the strainer was accounted for. The testing used only fine fibers. Nukon fiber was used to represent all fiber types in the plants. The mass of Nukon used in the tests was density-corrected to account for fiber types with different densities. The fiber was added in 1/16-inch batches for the first two batches and was increased to 1/8-inch for the final 3 batches. The total amount of fiber bounded both units. The licensee stated that there was no floating or settled debris after each batch and that the bed formed on the strainer was relatively uniform. The filter bags used in the test were sized to capture any fiber that penetrated the strainer. The bags were weighed before installation and after removal from the test loop to determine the mass of fiber captured. Each test used several sets of bags to provide data to develop a model for fiber penetration at varying debris loads.

Based on the Test 2 results, the licensee developed models for fiber penetration for each unit. The penetration models were developed using methods developed by the PWROG in WCAP-17788-P, "Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090)," Revision 1 (ADAMS Package Accession No. ML20010F181). The models included prompt penetration and shedding (i.e., long term release of fiber from the bed that passes downstream of the strainer). The models were used to predict the amount of fiber that would penetrate the strainer over time, considering plant flow rates and other plant-specific parameters.

ANO-1 Review

For ANO-1, the licensee chose to use Path 2 of the NRC staff review guidance for IVDE. The licensee credited the reactor building spray system for returning some fibrous debris to the sump pool. The remainder of the debris was assumed to accumulate at the core inlet. The licensee also stated that the calculated fiber amount arriving at the core was increased by 7 percent to account for uncertainties in the modeling of the test data.

The licensee provided the information requested by NRC staff guidance for B&W reactor designs (Path 2). The licensee confirmed that the calculated fiber amount at the core inlet is 77.94 grams/fuel assembly (g/FA), which is less than the fiber limit referenced in the guidance. Since ANO-1 is a B&W design and evaluated under Path 2 of the NRC Review Guidance for very low alternate flow path (AFP) resistance, no reactor vessel chemical effects evaluation is needed. The licensee also stated that boric acid precipitation (BAP) mitigation measures are inherent in the reactor design and operator action can be taken 24 hours following a LOCA as a defense-in-depth measure. The BAP mitigation measures provide flow paths that bypass the core inlet and any debris that accumulates there. Based on these facts, the licensee stated that ANO-1 is bounded by the WCAP-17788-P analysis for in-vessel downstream effects and LTCC is not challenged by this phenomenon.

<u>ANO-2 Review</u>

For ANO-2, the licensee chose to use Path 4 of the NRC staff review guidance for IVDE. The licensee credited the CSS for returning some fibrous debris to the sump pool. The remainder of the debris was assumed to accumulate at the core inlet. The licensee also stated that the calculated fiber amount arriving at the core was increased by 7 percent to account for uncertainties in the modeling of the test data.

The licensee provided the information requested by the NRC staff guidance for CE reactor designs (Path 4). The licensee confirmed that the calculated fiber amount at the core inlet is 72.52 g/FA, which is greater than the core inlet limit, but less than the total core fiber limit established by the guidance. Since ANO-2 is a CE design and evaluated under Path 4 of the NRC Review Guidance, the licensee provided a comparison of plant-specific in-vessel debris effects parameters to the assumptions used in the analysis and documented in the staff guidance. Table 3.n.1-3, "Summary of In-vessel Effects Parameters," of the licensee's submittal dated December 10, 2020, provides the comparison. The table demonstrates that all of the plant parameters fall within the bounds of the analysis except for the core inlet fiber amount. The licensee stated that the amount of fiber arriving at the core was greater than the core inlet limit, but less than the total in-core limit. The licensee stated that the fiber amount was scaled to account for differences between the assumed fuel design and the fuel used in the plant.

To address the issue that the fiber amount reaching the core inlet could be greater than the analyzed limit from WCAP-17788-P, the licensee stated that the analysis that developed the limit assumed a uniform debris distribution at the core inlet. The actual distribution would be skewed by higher flows entering some areas of the core inlet. The non-uniform distribution would result in lower head losses at the fiber limit than those predicted by the WCAP. Therefore, additional debris would have to accumulate at the core inlet before it would become fully blocked and AFPs are relied upon for LTCC. The licensee stated that it is reasonable to use the total core fiber limit as the core inlet limit considering the physics involved in the deposition of the fiber. The licensee stated that the amount of fiber that may reach the core inlet is less than the total core fiber limit and that LTCC will not be challenged.

The licensee stated on page 10 of Enclosure 2 of its Final Supplemental Response dated December 10, 2020, in part, "The later SSO [sump switchover] time and lower thermal power for ANO-2, compared with those analyzed in WCAP-17788, resulted in lower decay heat at the SSO time for ANO-2 than the WCAP analysis." The licensee also provided a more quantitative estimate of the decay heat expected at ANO-2 at the time of SSO. The NRC staff did not evaluate this quantitative estimate, which underpredicts the normalized decay heat modeled in

WCAP-17788-P for CE plants by a factor of greater than 10, insofar as it might justify the WCAP-17788-P analysis applicability. The NRC staff determined, however, that the later SSO time and lower rated thermal power level are sufficient qualitative considerations to conclude that the decay heat modeled in the CE analyses documented in WCAP-17788-P remains applicable to ANO-2.

The licensee stated that BAP mitigation measures, hot-leg switchover (HLSO), are taken within 5 hours following a LOCA. HLSO also provides a flow path to the core that bypasses any accumulation of debris at the core inlet.

The ANO-2 chemical precipitation time was determined using a precipitation map to compare the unit-specific sump aluminum concentration calculated by the WCAP-16530-NP-A method with the NaTB autoclave test results contained in WCAP-17788-P, Volume 5. ANO-2 used a 7.1 pH to determine aluminum solubility, which is a minimum solubility for the projected post-LOCA pH range of 7.1 to 8.0. The licensee also conservatively evaluated the precipitation temperature by assuming 12 parts per million aluminum concentration that is more than three times the maximum plant-specific calculated aluminum concentration. Using these assumptions and the ANO-2 post-LOCA temperature profiles, the aluminum precipitation map showed that no chemical precipitation would occur within 24 hours of a LOCA. Therefore, chemical precipitates would not form before HLSO (i.e., within 5 hours) or T_{block}, which is the earliest time that complete fuel inlet blockage can occur while not compromising LTCC (WCAP-17788-P) or inhibiting long term core cooling.

Based on these facts, the licensee stated that ANO-2 is bounded by the WCAP-17788-P analysis for IVDE for CE plants and LTCC is not challenged by this phenomenon.

NRC Staff Review

The NRC staff reviewed the information regarding the penetration testing and penetration model development. The NRC staff found that the testing was conducted in a manner that would result in conservative penetration compared to plant-specific conditions. Test practices were typical of those witnessed by the NRC staff during trips to test facilities. The NRC staff identified an issue in the licensee's description of strainer flow rates used during testing. The in-vessel submittal stated that the flow rate was based on a single-train flow rate for ANO-1. The NRC staff requested additional information to gain clarification on this issue in its letter dated July 16, 2021. By letter dated October 4, 2021, the licensee responded that the limiting test (Test 2) flow rate was based on the ANO-1 two-train operation. The NRC staff found the response and flow rate used acceptable.

The NRC staff did not understand how the penetration models were developed and, therefore, by letter dated July 16, 2021, requested additional information from the licensee to ensure that the modeling was performed adequately. By letter dated October 4, 2021, the licensee provided additional information regarding how the models were developed and clarified that the figures in the in-vessel submittal were examples for plant-specific scenarios, not necessarily bounding penetration models for each unit. Additionally, the licensee reiterated how the modeling was performed and pointed the staff to applicable information in the in-vessel submittal. The licensee provided additional details on the assumptions used in the modeling. The licensee also provided justification for the assumptions for the number and length of time that spray pumps were credited to take suction from the sump following swapover to recirculation. The NRC staff reviewed the responses and found that the modeling for each unit was performed adequately.

The NRC staff finds that the use of Path 2 from the NRC staff guidance is appropriate for ANO-1 since that guidance was developed specifically for B&W reactors. B&W reactors have very low AFP resistance, so the risk of core blockage is significantly reduced for this reactor type. The NRC staff finds that the licensee's evaluation of the effects of debris on LTCC for ANO-1 is acceptable and LTCC will not be challenged by in-vessel debris effects.

The NRC staff finds that the use of Path 4 from the NRC staff guidance is appropriate for ANO-2 since that guidance was developed specifically for CE reactors. The NRC staff has accepted that assuming a non-uniform debris distribution at the core inlet is a reasonable basis to allow licensees to use the total core fiber limit as the core inlet limit. The licensee also provided information that demonstrates that the decay heat is bounded by that considered in the analyses. The licensee also demonstrated that chemical effects will not occur prior to the time that AFPs can provide adequate flow for LTCC (T_{block}) or before HLSO is initiated, which bypasses blockage that may be accumulated at the core inlet. Therefore, the amount of fiber reaching the core will not adversely affect LTCC. The NRC staff finds that the licensee's evaluation of the effects of debris on LTCC for ANO-2 is acceptable and LTCC will not be challenged by in-vessel debris effects.

NRC Staff Conclusions

For the IVDE review area, the licensee provided sufficient information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the licensee's evaluation of this area for ANO 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. The evaluation of chemical effects on the reactor vessel is contained in Section 16.0 above.

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through October 4, 2021.

The ANO licensee has used a combination of head loss testing at Fauske Labs and autoclave testing at Westinghouse to perform a chemical effects evaluation.

The licensee's overall approach is technically sound. The licensee used WCAP-16530 NP to calculate the projected chemical precipitate loads for ANO. The licensee added the entire chemical load to the flume tests at Fauske and Associates, taking credit for the fact that the aluminum-based precipitates would not precipitate immediately (i.e., full WCAP precipitate load head loss was applied against a head loss margin at 197 °F). The licensee demonstrated that its chemical effects precipitation temperature assumptions were conservative by performing autoclave testing at Westinghouse. The test results showed that precipitation occurred at temperatures significantly less than the assumed precipitation temperature.

The licensee increased the ANO-1 sump strainer from 200 ft^2 to approximately 2,700 ft^2 during the spring 2007 RFO. The licensee increased the ANO-2 sump strainer from 154 ft^2 to approximately 4,800 ft^2 during the fall 2006 RFO.

ANO switched the chemical used to buffer the post-LOCA sump pool pH. For ANO-1, the licensee switched from sodium hydroxide to NaTB. For ANO-2, the licensee switched from TSP to NaTB, with an equilibrium sump pH between 7.1 and 8.0.

The licensee performed head loss testing at Fauske Labs that was witnessed by NRC staff. These tests used WCAP-16530-NP sodium aluminum silicate chemical surrogate added to the flume after all plant debris had formed a bed on the CCI pocket strainer test section. Since the head loss values were too high if all chemical precipitate was added while maintaining the early post-LOCA NPSH margin, the licensee subsequently performed plant-specific autoclave testing at Westinghouse to provide a basis for delaying the consideration of chemical precipitate formation until additional NPSH margin was available at lower temperatures. Head loss with the full chemical precipitate load is compared against the limiting NPSH for structural purposes (10.8 ft of water) and determined to be acceptable. The NRC staff also notes that the additional chemical effects testing that was performed as part of WCAP-17788-P, Volume 5 confirmed that no early precipitation occurred with test conditions representative of the ANO-1 and ANO-2 post-LOCA environments.

<u>NRC Staff Conclusion</u>

For the chemical effects 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 licensee's evaluation of this area for ANO is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02.

18.0 LICENSING BASIS

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the changes associated with GL 2004-02. The NRC staff review is based on documentation provided by the licensee through September 15, 2008.

The plant modifications at ANO-1 implemented in response to GL 2004-02 that required changes to the licensing basis are listed below with the corresponding dates for licensing basis changes:

- ER-ANO-2001-1205-001: This modification revised the ANO-1 Safety Analysis Report (SAR) to describe the upgraded sump strainer, the deletion of the sump vortex suppressor, and relocation of sump level instrumentation. The sump strainer modification was installed in spring 2007 during the 1R20 RFO.

- EC–2245: This modification reduced the sodium hydroxide (NaOH) tank concentration to values within the existing range specified in the ANO-1 TSs in December 2007. The licensee reported that the new NaOH concentration range was being administratively controlled until the approval of the license amendment request dated July 30, 2008. The NRC staff approved the ANO-1 license amendment in January 2009 (ADAMS Accession No. ML083050176).

- EC–2243: This engineering change revised the ANO-1 design basis for ECCS/RBS recirculation to show that new regulatory requirements resulting from GL 2004-02 are satisfied. This change, approved by Entergy on August 12, 2008, also revised the ANO-1 SAR to describe changes to ECCS and RBS NPSH analyses resulting from GL 2004-02 requirements.

The plant modifications at ANO-2 implemented in response to GL 2004-02, which required changes to the licensing basis, are listed below with the corresponding dates for the licensing basis changes:

- ER-ANO-2001-1208-002 and ER-ANO-2001-1208-003: These modifications revised the ANO-2 SAR to describe the upgraded sump strainer, relocation of selected plant equipment to allow for installation of new strainer modules, and installation of the sump plenum. The sump strainer modifications were installed in fall 2006 during the 2R18 RFO.

- EC – 1640 and EC – 1641: These modifications supported a license amendment that revised the ANO-2 SAR and TSs for replacement of pH buffer TSP with an alternate buffer (NaTB). The modification was installed in spring 2008 during the 2R19 RFO.

- EC – 4389: This modification revised the ANO-2 SAR to show the updated heat sink surface area as a result of stiffeners added to the containment sump plenum doors and hatches. This modification was installed in spring 2008 during the 2R19 RFO. The licensee reported in its supplemental response that the SAR change for this modification is being processed.

- EC – 2244: This engineering change revised the ANO-2 design basis for ECCS/CSS recirculation to show that new regulatory requirements resulting from GL 2004-02 are satisfied. This change, approved by Entergy on August 14, 2008, also revised the ANO-2 SAR to describe changes to the CSS and HPSI pump NPSH analyses resulting from GL 2004-02 requirements.

NRC Staff Conclusion

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

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

Principal Contributors: S. Smith, NRR
A. Russell, NRR
P. Klein, NRR
M. Yoder, NRR
B. Lehman, NRR

Date: March 29, 2022

SUBJECT: ARKANSAS NUCLEAR ONE, UNITS 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 MARCH 29, 2022

DISTRIBUTION:
PUBLIC
PM File Copy
RidsACRS_MailCTR Resource
RidsNrrDorlLpl4 Resource
RidsNrrDssStsb Resource
RidsNrrLAPBlechman Resource
RidsNrrPMANO Resource
RidsRgn4MailCenter Resource
SSmith, NRR
ARussell, NRR
MYoder, NRR
PKlein, NRR

ADAMS Accession No. ML22061A056 ***by e-mail**

OFFICE	NRR/DORL/LPL4/PM*	NRR/DORL/LPL4/LA*	NRR/DSS/STSB/BC*
NAME	TWengert	PBlechman	VCusumano
DATE	3/7/2022	3/7/2022	12/21/2022
OFFICE	NRR/DNRL/NCSG/BC*	NRR/DORL/LPL4/BC*	NRR/DORL/LPL4/PM*
NAME	SBloom	JDixon-Herrity	TWengert
DATE	3/7/2022	3/29/2022	3/29/2022

OFFICIAL RECORD COPY