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

July 29, 2021

Mr. James M. Welsch
Senior Vice President, Generation
and Chief Nuclear Officer
Pacific Gas and Electric Company
Diablo Canyon Nuclear Power Plant
P.O. Box 56, Mail Code 104/6
Avila Beach, CA 93424

SUBJECT: DIABLO CANYON NUCLEAR POWER PLANT, 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 Mr. Welsch:

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

By letter dated May 14, 2013 (ADAMS Accession No. ML13135A070), Pacific Gas and Electric Company (the licensee) stated that they would pursue Option 2 (risk-informed) for the closure of GSI-191 and GL 2004-02 for Diablo Canyon Nuclear Power Plant, Units 1 and 2 (Diablo Canyon). Subsequently, by letter dated April 30, 2020 (ADAMS Accession No. ML20121A095), the licensee determined that they would maintain Option 2 but use a deterministic resolution.

On July 23, 2019 (ADAMS Package Accession No. ML19203A303), GSI-191 was closed. It was determined that the technical issues identified in GSI-191 were now well understood, and therefore, GSI-191 could be closed. Prior to and in support of closing GSI-191, the NRC staff issued a technical evaluation report on in-vessel downstream effects (ADAMS Accession Nos. ML19178A252 and ML19073A044 (not publicly available, proprietary information)). Following the closure of GSI-191, the NRC staff also issued the review guidance for in-vessel downstream effects, "NRC Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of Generic Letter 2004-02 Responses" (ADAMS Accession No. ML19228A011), to support review of the GL 2004-02 responses.

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

The stated purpose of GL 2004-02 was focused on demonstrating compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.46. Specifically, GL 2004-02 requested addressees to perform an evaluation of the emergency core cooling system and containment spray system recirculation and, if necessary, take additional action to ensure system function considering the potential for debris to adversely affect long-term core cooling. The NRC staff finds the information provided by the licensee demonstrates that debris will not inhibit the 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.

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

Enclosed is the summary of the NRC staff's review. If you have any questions, please contact me at 301-415-3168 or via e-mail at Samson.Lee@nrc.gov.

Sincerely,

***/RA/***

Samson S. Lee, Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-275 and 50-323

Enclosure:
NRC Staff Review of GL 2004-02
for Diablo Canyon

cc: Listserv

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

# U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW

# OF THE DOCUMENTATION PROVIDED BY

# PACIFIC GAS AND ELECTRIC COMPANY

# FOR DIABLO CANYON POWER PLANT, UNITS 1 AND 2

# DOCKET NOS. 50-275 AND 50-323

# CONCERNING RESOLUTION OF GENERIC LETTER 2004-02

# POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING

# DESIGN-BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

## 1.0 INTRODUCTION

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

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

It is also possible that some debris would 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 (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 would 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 GL 2004-02 from the Committee to Review Generic Requirements (ADAMS Accession No. ML040840034).

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

By letter dated May 28, 2004 (ADAMS Accession No. ML041550661), the Nuclear Energy Institute (NEI) submitted a report describing a methodology for use by PWRs in the evaluation of containment sump performance. NEI requested that the NRC review the methodology. The methodology was intended to allow licensees to address and resolve GSI-191 issues in an expeditious manner through a process that starts with a conservative baseline evaluation. The baseline evaluation serves to guide the analyst and provide a method for quick identification and evaluation of design features and processes that significantly affect the potential for adverse containment sump blockage for a given plant design. The baseline evaluation also facilitates the evaluation of potential modifications that can enhance the capability of the design to address sump debris blockage concerns and uncertainties and supports resolution of GSI-191. The report offers additional guidance that can be used to modify the conservative baseline evaluation results through revision to analytical methods or through modification to the plant design or operation.

By letter dated December 6, 2004 (ADAMS Accession No. ML043280641), the NRC issued an evaluation of the NEI methodology. The NRC staff concluded that the methodology, as approved in accordance with the NRC staff safety evaluation (SE), provides an acceptable overall guidance methodology for the plant-specific evaluation of the ECCS or CSS sump performance following postulated DBAs.

In response to the NRC staff SE conclusions on NEI 04-07, “Pressurized Water Reactor Sump Performance Evaluation Methodology” (ADAMS Accession Nos. ML050550138 and ML050550156), the PWR 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.

- 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.

- 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.

The NRC staff reviewed the TRs and found them acceptable to use (as qualified by the limitations and conditions stated in the respective SEs).[1] 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.

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

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[1] The NRC staff SEs are included in the respective approved TRs. The NRC staff SEs are also available separately: SE by NRR, TR WCAP-16406-P, Revision 1, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," PWROG Project No. 694 (ADAMS Accession No. ML073520295); Final SE for PWROG TR WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191" (ADAMS Accession No. ML073520891); Final SE by NRR, TR WCAP-16793-NP, Revision 2, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," PWROG Project No. 694 (ADAMS Accession No. ML13084A154).

Performance," dated July 9, 2012 (ADAMS Accession No. ML121320270). The options are summarized as follows:

- Option 1 requires 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 are low fiber plants with less than 15 grams of fiber per fuel assembly.

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

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

    - Option 2 Risk Informed: Use the South Texas Project pilot approach.

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

The options allowed industry alternative approaches for resolving GSI-191. The Commission issued Staff Requirement Memorandum SECY-12-0093 on December 14, 2012 (ADAMS Accession No. ML12349A378), approving all three options for closure of GSI-191.

By letter dated May 14, 2013 (ADAMS Accession No. ML13135A070), Pacific Gas and Electric Company (the licensee) stated that they would pursue Option 2 (risk-informed) for the closure of GSI-191 and GL 2004-02 for Diablo Canyon Nuclear Power Plant, Units 1 and 2 (Diablo Canyon). Subsequently by letter dated April 30, 2020 (ADAMS Accession No. ML20121A095), the licensee determined that they would maintain Option 2 but use a deterministic resolution.

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 NRC staff issued a technical evaluation report on in-vessel downstream effects (ADAMS Accession Nos. ML19178A252 and ML19073A044 (not publicly available, proprietary information)). Following the closure of GSI-191, the NRC staff also issued the review guidance for in-vessel downstream effects, "NRC Staff Review Guidance for In-Vessel Downstream Effects Supporting Review of Generic Letter 2004-02 Responses" (ADAMS Accession No. ML19228A011), to support review of the GL 2004-02 responses.

The following is a list of documentation to and from the licensee regarding GL 2004-02:

| RESPONSES TO GL 2004-02 | | |
|---|---|---|
| DOCUMENT DATE | ADAMS ACCESSION NUMBER | DOCUMENT |
| March 4, 2005 | ML050770407 | Initial Response to GL |
| April 1, 2005 | ML051030182 | Initial Response (Corrected) |
| June 2, 2005 | ML051530252 | 1st NRC RAI |
| July 21, 2005 | ML052090198 | Licensee Response to RAI |

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|---|---|---|
| September 1, 2005 | ML052500518 | Supplemental Information |
| February 9, 2006 | ML060380368 | 2nd NRC RAI |
| September 1, 2006 | ML062560070 | Supplemental Information |
| February 1, 2008 | ML080420438 | 2nd Supplemental Response |
| July 10, 2008 | ML081980104 | Revised 2nd Supplemental Response |
| August 1, 2008 | ML082050608 | 3rd NRC RAI |
| November 3, 2008 | ML083190020 | Licensee Response to RAI |
| June 16, 2009 | ML091770158 | Supplemental Information |
| October 15, 2009 | ML092310763 | 4th NRC RAI |
| May 14, 2013 | ML13135A070 | Closure Option |
| April 30, 2020 | ML20121A095 | Final Supplemental Response |
| March 2, 2021 | ML21062A064 | 5th NRC RAI |
| April 15, 2021 | ML21105A147 | RAI Responses |

The NRC staff reviewed the information provided by the licensee in response to GL 2004-02 and all responses to the 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 Item 2(b) requested a general description of and implementation schedule for all corrective actions. The following is a list of major corrective actions completed by the licensee at Diablo Canyon in support of the resolution of GL 2004-02:

- Installed a larger sump strainer assembly (with approximately 5 times the surface area of the strainer upgraded in the tenth refueling outages, and approximately 40 times the area of the original screens).
- Modified the doors and hatches to allow water to flow freely to the sump.
- Modified the reactor cavity door to allow more debris to flow into the reactor cavity inactive sump.
- Installed debris interceptors to reduce debris arriving at the strainer.
- Removed cable tray fire stops inside the crane wall to reduce potential debris during a LOCA.
- Installed more robust jacketing and insulation systems to reduce potential debris during a LOCA.
- Installed tray covers to protect the pressurizer heater cable insulation in cable trays below the pressurizer.
- Installed reflective metal insulation (RMI) and stainless-steel jacketed Temp-Mat on the replacement steam generators to reduce potential fibrous debris during a LOCA.

- Increased the technical specifications minimum refueling water storage tank (RWST) water volume from 400,000 gallons to 455,300 gallons to provide greater sump inventory.

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

## 3.0 BREAK SELECTION

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

### NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through April 30, 2020.

The licensee used the guidance from NEI 04-07 and the associated SE except for moving breaks at 5 foot (ft.) intervals. Instead, the licensee postulated breaks at each weld inside the crane wall. At each weld location, the licensee postulated double ended guillotine breaks, and partial breaks at various orientations. This approach is more realistic than the method described in NEI 04-07 and the associated SE because welds are the most likely break locations. The method is also more comprehensive because it considers more break locations and break configurations than the guidance requires. The NRC staff noted that the licensee approach is acceptable because it is systematic and thorough as per the guidance of NEI-04-07 and the associated SE, and it covers the likely break locations.

Breaks outside the crane wall were not evaluated for debris generation because the largest lines and greatest quantity of debris are located inside the wall. The NRC staff finds that it is acceptable to exclude potential breaks outside the crane wall based on the much smaller magnitude of debris that could be generated by breaks outside the crane wall.

The break selection evaluation did not include secondary line breaks because secondary line breaks are not within the design-basis events that require recirculation. The NRC staff finds that the licensee's break selection is acceptable.

### NRC Staff Conclusion

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

## 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 April 15, 2021.

The licensee stated that the destruction pressures and associated ZOI radii for debris generation are generally taken from the SE on NEI 04-07. Adoption of these ZOIs is acceptable. Materials for which the approved ZOI was not adopted are discussed below.

The licensee stated that encapsulated Temp-Mat was assigned a ZOI of 3.7D based on TR WCAP-17561-P, Volume 1, Revision 0, “Testing and Analysis to Reduce Debris Generation Zones of Influence for GSI-191” (ADAMS Package Accession No. ML121460195) (not-publicly available, proprietary information). The NRC staff reviewed the TR and determined that the methodology used was generally acceptable. However, the NRC staff found that the testing for Temp-Mat could be non-conservative with respect to some plant installations. In its testing, the licensee included enough Temp-Mat to bound the amount that would be generated using an approved ZOI of 11.7D for unencapsulated Temp-Mat. Therefore, the use of the smaller 3.7D ZOI for encapsulated Temp-Mat is not an issue for the current plant configuration. The NRC staff requested that the licensee justify the continued credit for the smaller ZOI because future plant changes or discoveries of Temp-Mat could result in a non-conservative calculation with respect to its debris amount. In its response, the licensee considered two cases, new Temp-Mat installations, and the discovery of previously unidentified Temp-Mat within containment. The licensee stated that design change procedures discourage the use of fibrous insulation types in containment. Additionally, the licensee stated that the fabrication and installation of Temp-Mat is controlled to comply with the WCAP-17561-P tested configuration. With respect to discovery of previously unidentified Temp-Mat within containment, the licensee stated that initial operability determinations would assume that all the discovered insulation would fail and be assessed against existing margins. If a more detailed analysis was required, the licensee stated that the debris generation calculation would consider the limitations associated with application of WCAP-17561-P in the calculation of Temp-Mat debris amounts. The NRC staff noted that the current evaluation and head loss testing is conservative with respect to the amount of Temp-Mat because the analysis included enough debris to bound the amount that could be generated if the approved ZOI (for unencapsulated Temp-Mat) of 11.7D were used. This provides a significant margin that is very unlikely to be challenged by any discovery of encapsulated Temp-Mat. With respect to the addition of encapsulated Temp-Mat, the NRC agrees that the licensee guidance is adequate to prevent the installation of significant amounts of fibrous debris within a potential ZOI without thorough evaluation that would adequately consider the necessary aspects of the modification. Therefore, the NRC staff finds that the licensee provided information that justifies use of the 3.7D ZOI for encapsulated Temp-Mat, and that the current analysis is conservative with respect to the Temp-Mat debris source term.

The licensee adopted a 17D ZOI for thermal insulating wool (a fiberglass insulation system). The licensee stated that the material used the accepted ZOI for Nukon because the material is compressed to have a greater density than Nukon and is protected by a multi-banded jacketing system. The NRC staff finds that the use of the Nukon ZOI was acceptable because higher density fibrous materials generally have smaller ZOIs and because of the protection provided by the banded stainless-steel jacketing. Additionally, the thermal insulating wool is installed only on elbows of calcium-silicate (Cal-Sil) insulated lines of 2 inches and smaller, so it is a small source of fiber.

The licensee assumed that pressurizer heater cables had a ZOI of 17D. The densities of the materials that make up the cable insulation are much denser than Nukon, which has an approved ZOI of 17D. The NRC staff finds that the 17D ZOI for pressurizer heater cables is acceptable because higher density fibrous materials generally have a smaller ZOI. The NRC staff also observed that the pressurizer heater cables are more robust than Nukon insulation by inspection.

The licensee assigned a ZOI of 11.7D to Min-K protected by Temp-Mat. The Min-K is installed in a floor penetration in the pressurizer cubicle. Any break in the cubicle would have to destroy the Temp-Mat before damaging the Min-K. Therefore, the NRC staff finds the use of an 11.7D ZOI acceptable for this specific Min-K application.

The licensee stated that vapor barrier material is bonded to stainless steel jacketing used in a Cal-Sil insulation system. The amount of vapor barrier debris was determined from the amount of Cal-Sil damaged by LOCA jets based on the surface area of the jacketing. The NRC staff finds this acceptable because the vapor barrier amount is directly related to the Cal-Sil damaged.

The licensee used a reduced ZOI for Temp-Mat insulation generated from reactor nozzle breaks. The licensee stated that the ZOI size was developed using the American National Standards Institute (ANSI)/American Nuclear Society (ANS)-58.2, "Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture," jet methodology. The NRC has accepted the use of this methodology to determine ZOI sizing for restrained breaks. However, the licensee did not describe how the break opening sizes were determined. The NRC requested that the licensee provide additional details as to how the ZOIs were determined. The licensee stated that the jet was modeled using the ANSI 58.2-1988 model for circumferential breaks with ends restrained. The licensee determined a ZOI length by first calculating the mass flux from the postulated pipe separation using the NRC staff recommended Henry-Fauske model. Based on the mass flux, the licensee used the NRC-approved methodology to calculate the jet pressure, along the jet centerline, at various distances from the break. The destruction pressure for Temp-Mat is 10.2 pounds per square inch gauge (psig). The licensee determined the length of the jet at the jet centerline where the pressure was equal to 10.2 psig and used this length to assess the zones where damage to the Temp-Mat could occur. Use of the jet length is conservative since the length is based on the jet centerline and pressure decreases with increase in radial distance from the centerline. The jet length, at 10.2 psig, was superimposed over a model of the RCS piping to determine areas within which damage could occur. The NRC staff finds the licensee's method acceptable because it follows staff guidance and uses a conservative jet length to identify potential damage zones for Temp-Mat.

RMI was considered to have a ZOI of 28.6D, which is conservative. The NRC staff found that the size distribution for RMI was acceptable.

The licensee identified the breaks that could generate and transport the largest quantities of fiber or Cal-Sil to the strainers. These breaks were evaluated separately for debris generation and transport. The maximum debris generation case for fiber was combined with the maximum debris generation case for Cal-Sil. So, the overall evaluation conservatively assumed that the maximum fibrous debris and the maximum Cal-Sil debris would arrive at the strainer. This clearly bounds any debris combination that would be generated by a single break.

The licensee also evaluated generation of non-break specific debris like valve tags, stickers, etc. These debris amounts were verified by plant walkdowns, reviews of plant drawings and computer aided design models. The NRC staff finds that the methods used for identification of these debris sources are acceptable. The licensee identified, after transport is accounted for, a sacrificial surface area of 205.16 square feet ($ft^2$) due to miscellaneous debris.

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 Diablo Canyon 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 April 30, 2020.

The NRC staff reviewed the licensee's responses and finds that the licensee's assumed debris characteristics were acceptable because they were consistent or more conservative than the guidance in the SE on NEI 04-07. Most damaged insulating material was assumed to be 100 percent fines. RMI sizing is consistent with approved guidance.

The licensee assumed that Temp-Mat damaged by a LOCA would become 100 percent fines unless it was postulated to remain in intact blankets. This assumption is conservative because it ignores that some Temp-Mat would be small and large pieces, which would not transport to the strainer. All fine debris was assumed to transport to the strainer except for a small amount sequestered in inactive volumes.

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 Diablo Canyon 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 April 30, 2020.

The licensee stated that the latent debris evaluation assumed debris composition and properties in accordance with the guidance in the NRC SE to NEI 04-07. Comprehensive walkdowns were performed using guidance provided in NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments", which included extensive sampling for latent debris (dust and lint) considering guidance in NEI 04-07. The NRC staff finds that the use of 100 pound-mass (lbm) as the bounding value is conservative based upon the 59.2 lbm value determined by measurement and extrapolation. The value was taken from Diablo Canyon, Unit 1 and applied to Diablo Canyon, Unit 2 because the Unit 1 value was greater.

The licensee provided the amount of sacrificial strainer area in Section 4.0 discussed above. The sacrificial area allotted was found to be acceptable based on the amount of miscellaneous debris predicted to be generated and transport to the strainer. The sacrificial strainer area assigned to the strainer is 205.16 $ft^2$.

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 Diablo Canyon 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 April 30, 2020.

The licensee stated that the transport analysis was conducted based on the NEI 04-07 guidance as approved by the NRC staff SE. The transport analysis included refinements discussed in the appendices of the NRC staff SE. The licensee evaluated the four phases of transport: blowdown, washdown, pool fill, and recirculation. The evaluation of each phase was fed into logic trees to allow calculation of the overall debris transport from the time of debris generation to the time when no additional transport is predicted. An example logic tree was provided in the submittal. Some areas of interest are discussed below.

The licensee used a computational fluid dynamics (CFD) model of the containment recirculation pool to evaluate recirculation transport. The model included representation of fluid falling and draining into the pool, and fluid being extracted from the pool through the strainers. Fluid entering the pool was assumed to come from containment spray (CS) drainage and flow out of the break. The CFD was run to determine steady-state flow velocities and turbulence values in the sump pool. These values were compared against transport metrics for various materials (including various sizes of each debris type) to determine how much debris would transport to the strainers. The transport metrics were determined by testing.

The licensee's evaluation credited debris interceptors for inhibiting the transport of some coating chips. The credit for debris holdup was based on plant-specific testing. Fine debris was not assumed to be trapped by the debris interceptors. The debris interceptors were also credited with trapping all sunken small or large pieces of debris unless the turbulence at the interceptor was great enough to suspend the debris. The NRC staff reviewed the credit for holdup by the debris interceptors and found it acceptable.

The licensee assumed that Temp-Mat could erode due to turbulence in the pool and that the eroded fines could transport to the strainer. It was assumed that 10 percent of Temp-Mat in the pool would erode and 1 percent of Temp-Mat held up above the pool would erode into fines. These values are consistent with NRC staff guidance.

The licensee stated that it calculated that greater than 15 percent of debris in the pool during pool fill would be washed to the inactive reactor cavity. However, the licensee limited the credit for debris capture in inactive volumes to 15 percent per NRC staff guidance. Based on a review of the transport fractions for the most detrimental debris types, the NRC staff finds that the credit for debris transport to inactive volumes was conservative.

The licensee estimated transport of coating chips based on the CFD analysis and debris interceptor testing. The NRC staff reviewed the coating chip transport, including a review of the coating debris characteristics assumed for the transport analysis. The NRC staff finds that the transport of coating chips was estimated acceptably.

<u>NRC Staff Conclusion</u>

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

## 8.0 HEAD LOSS AND VORTEXING

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

<u>NRC Staff Review</u>

The NRC staff review is based on documentation provided by the licensee through April 30, 2020.

The licensee stated that it conducted updated head loss testing of the strainer in 2016. The majority of the head loss and vortexing section of the analysis is based on this testing. The licensee stated that they performed both thin bed and full-load tests in accordance with NRC staff guidance. The test strainer was constructed to model the plant strainer geometrically and hydraulically. The licensee stated that the debris loads and flow through the strainer were scaled based on the area of the plant strainer to the test strainer. Debris used in the testing was either the actual material or an acceptable surrogate. The debris preparation and introduction were stated to be in accordance with approved NRC guidance for each test.

The NRC staff noted that the test debris included both the maximum potential fibrous debris load and the maximum potential Cal-Sil debris loads predicted to arrive at the strainer from the limiting break for each. This combination of debris would not occur since the maximum load from two separate limiting breaks was combined. In addition, the coating debris amount is largely independent of break location, so a limiting coating amount was also included in the tests. The NRC staff finds that the debris amounts included in the test are conservative and likely very conservative for almost all potential LOCA breaks.

The licensee did not add all of the chemical debris calculated to reach the strainer because addition of further chemical debris resulted in reduced head loss. The licensee used the peak head loss from the full debris load test in its analyses since this was the highest head loss attained during testing. The maximum peak head loss without chemicals was measured to be 0.437 pounds per square inch (psi). With chemicals, the maximum peak head loss was measured at 0.550 psi. The stabilized head losses were lower but were not used.

The licensee performed temperature and flow sweeps during testing to assist in characterization of the flow through the debris bed.

The licensee stated that the strainer is fully submerged for large break LOCAs (LBLOCAs) prior to the switch from injection to recirculation. For the small break LOCAs (SBLOCAs) the strainer is only partially submerged at the time of swapover to recirculation. The licensee performed a vortex evaluation based on the calculated submergences and testing of a prototypical strainer under loaded and clean conditions. The evaluation concluded that vortexing would not result in air ingestion to the ECCS and CS pumps. The NRC staff finds that the vortex evaluation was acceptable because it was based on strainer tests conducted under the most limiting strainer loading and submergence conditions.

The licensee stated that the head loss evaluation was conservative because the flow rate used for the analysis is higher than the steady-state flow rate that will be present after the swapover to recirculation is completed. As noted above, the debris loads were also conservative.

The licensee stated that even though the strainer is only partially submerged at the beginning of the SBLOCA that it meets the guidance in Regulatory Guide (RG) 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident." The guidance is that the head loss is limited to less than half of the strainer submergence. The licensee stated that the head loss was conservatively assumed to be 0.758 ft. while the front strainer submergence is 1.01 ft. and the rear strainer submergence is 1.79 ft. The NRC staff was unable to conclude that the configuration at the start of recirculation for the SBLOCA is consistent with the guidance in RG 1.82 because the head loss is greater than one half of the submergence of the front strainer disks. The NRC staff asked the licensee for clarification on this issue, including whether additional water from the RWST is pumped into the containment during responses when CS has and has not been initiated. The NRC staff requested that the licensee discuss timing and changes in submergence during these scenarios. The licensee responded that the submittal stated that the submergence values in the submittal were **half** (emphasis added) of the submerged depth of the strainer, not the absolute submergence depths. The NRC staff finds that the strainer meets the guidance for strainer head loss and submergence for partially submerged strainers, and that the licensee's design provides acceptable margin for this plant condition.

The licensee stated that clean strainer head loss (CSHL) was calculated for the strainer disk and plenum head losses separately. The disk head loss assumed the highest disk approach velocity associated with clean strainer conditions. The plenum head loss was calculated assuming uniform flow through the strainer, which results in a conservative plenum head loss. Combining these results in a conservative CSHL for the overall strainer. The CSHL was calculated for both single and dual residual heat removal (RHR) pump operation. Because of the plenum arrangement, the single pump operation results in the limiting CSHL, which was calculated at 1.726 psi. The licensee also stated that the CSHL was calculated at 100 degrees Fahrenheit (°F) and that no temperature correction was used for the analysis. The NRC staff finds that the CSHL was calculated acceptably because of the conservative assumptions used.

The licensee stated that the total head loss was calculated by combining the maximum debris head loss with the maximum CSHL. The debris head loss was corrected for temperature and included credit for lack of chemical precipitation until the fluid temperature decreased to less than 180 °F. The temperature correction was based on flow sweeps conducted during testing. The NRC staff found the head loss calculations to be acceptable because they were performed using staff accepted methods and were based on plant-specific test results.

The licensee performed a flashing analysis. The licensee used conservatism in calculating the fluid pressure downstream of the strainer. The head loss resulting from the most limiting conditions was used (limiting flow rate and lowest temperature, which includes chemical head loss). Using the higher chemical head loss is conservative because chemical effects are not predicted to occur until the fluid temperature is less than 180 °F when significant subcooling would be present. The head loss included CSHL. This is conservative because the plenum contribution to CSHL occurs with added submergence that would suppress flashing. The minimum strainer submergence was used. The submergence increases significantly during the swapover to recirculation. The licensee performed the flashing calculation only for the LBLOCA. For the LBLOCA, the licensee stated that 1.02 psi was credited to show that flashing across the strainer will not occur. The licensee stated that the conditions for the SBLOCA (breaks less than 6 inches) are less limiting than larger breaks. The NRC staff finds that head losses for the small breaks would be much lower than those for the larger breaks, especially considering the conservatisms included in the head loss analysis as discussed in this section. Although the submergence is lower for the SBLOCA, the LBLOCA case is limiting. The licensee noted that the pressure in containment would be much larger than the 1.02 psi credited to prevent flashing. (No containment pressure was credited in the NPSH calculations.) The NRC staff finds that the flashing evaluation showed that the pressure available in containment would be significantly greater than that necessary to suppress flashing and that the required credit would be lower than that calculated due to the conservatism used. Therefore, the flashing evaluation is acceptable.

The licensee performed a degasification analysis to determine the void fraction that could be present at the pump suction. The licensee used conservative inputs to calculate the amount of gas that could come out of solution and transport to the pump suctions. The maximum resulting void fraction at the pump suction was calculated to be 0.17 percent. The NRC staff finds that the void fraction analysis was performed acceptably. This issue is further evaluated in the NPSH section because it was not clear how the potential effects of voiding on pump operation were considered. As discussed in the NPSH section, the NRC staff found that the licensee treated the potential for void fraction at the pump suction acceptably.

NRC Staff Conclusion

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

## 9.0 NET POSITIVE SUCTION HEAD

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

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through April 15, 2021.

The licensee provided the information described in the content guide. The methodology used is a standard industry practice for calculation of NPSH margin and used a combination of realistic and conservative assumptions.

The Diablo Canyon ECCS and CSS each include two trains of pumps. Each ECCS train consists of one centrifugal charging pump (high pressure), one safety injection pump (intermediate pressure), and one RHR (low pressure) discharging through a RHR heat exchanger. Each CSS train has two pumps that operate only during injection from the RWST. After swapover to sump recirculation, the RHR pumps supply the CS function if required. On actuation of the safety injection signal (start of the injection phase) all pumps automatically start taking suction from the RWST with the ECCS pumps injecting into all four cold legs. Due to relatively low shutoff head, the RHR pumps will not inject to the RCS until the pressure is reduced to about 170 psig. When the RWST reaches the low-level alarm setpoint, the RHR pumps are automatically tripped. Recirculation from the sump is manually initiated by opening the containment sump suction valves and closing the RWST suction valves. The centrifugal charging pumps and safety injection pumps are aligned to take suction from the RHR pump discharge.

A CSS actuation signal or manual actuation starts the CSS pump flows to their respective CS headers. Before RWST level drops to 4 percent level, the CS pumps are secured. The CS pumps do not take suction through the recirculation sump. The RHR pumps provide CS if required.

The licensee stated that the maximum recirculation single train RHR pump flow is 4,921 gallons per minute (gpm) with a maximum two pump flow of 7,769 gpm. This represents the highest strainer flow rate. The licensee stated that a flow rate of 7,769 gpm was conservatively used in the NPSH analysis even though it would only be present momentarily until the RHR pump flow to the cold legs is throttled per the emergency operating procedures. The licensee further stated that if only one RHR pump is operating, the maximum flow rate of 4,921 gpm occurs only momentarily until the pump is throttled per the emergency operating procedures. During hot-leg recirculation the maximum flow rate through the strainer is 4,900 gpm.

The minimum containment water level at the start of ECCS recirculation for a LBLOCA is 93.7 ft. In its RAI response, the licensee stated that the minimum water level calculated for the SBLOCA (93.17 ft.) is used in the NPSH analysis. This occurs at the start of recirculation and results in a submergence of 0.26 ft. for the front strainer disks and 0.03 ft. for the rear disks. The water level increases to 94.97 ft. after the swapover to recirculation is complete and the CS pumps have been secured. The CS pumps continue to pump water from the RWST into containment until they are secured. This increases the containment sump level. The resulting submergence is 1.53 ft. for the front disks and 1.30 ft. for the rear disks.

For a SBLOCA at the start of an ECCS recirculation, the sump level could be lower. The minimum level at the start of recirculation for the SBLOCA is 93.17 ft., which leaves the strainer partially submerged. The licensee stated that the top 0.27 ft. of the front disks and 0.5 ft. of the rear disks are not submerged at this level. In the head loss and vortexing section, the NRC staff asked for clarification on how the partial submergence could affect the head loss evaluation. However, the sump level also affects the NPSH analysis. The NRC asked the licensee to describe how the potentially lower sump level was accounted for in the NPSH analysis. The NRC staff recognized that there is adequate NPSH margin to account for the potentially lower sump level but asked the licensee to clarify the effect of sump level in case future changes to NPSH calculations are required. The licensee responded that the sump level calculation assumes an additional 3 minutes of injection from the CSS after the RWST low-level trip is received, and that the inventory added during this time is insignificant (for cases where CSS is initiated). The licensee stated that the sump level was evaluated for break sizes between 1.5 and 6 inches, both with and without CS under minimum and maximum safeguard conditions. The licensee also stated that the 93.17 ft. level was determined from the evaluation of a 4-inch break with CS and minimum safeguards. The licensee also stated that the minimum level is based on a conservatively small inventory injected from the accumulators and provided a comparison case for a 2-inch break and no CSS actuation. Using a realistic injection volume from the accumulators, the comparison case results in a level higher than the minimum level calculated for the 4-inch break in the submittal. The licensee stated that the NPSH analysis uses the SBLOCA level of 93.17 ft. The NRC staff finds that the licensee calculated an appropriate minimum water level for the analysis. The NRC staff also recognizes that small breaks generate less debris and result in less challenging conditions for the sump strainers and potentially for other components required to respond to the LOCA. For example, debris generation is reduced, sump temperatures are reduced, and flow rates through the ECCS pumps may be reduced. Therefore, the NRC staff finds the response to this RAI acceptable.

For both the SBLOCA and LBLOCA sump level calculations, the licensee used conservative methods consistent with NRC guidance. The licensee credited sources of inventory only when appropriate and accounted for holdups that would decrease inventory. The licensee used conservative assumptions for physical properties of water.

The licensee stated that maximum sump water temperature at the time ECCS recirculation flow begins was conservatively assumed to be 261 °F to maximize chemical effects. The licensee stated that the temperature did not impact the NPSH evaluation because the containment pressure was always assumed to be the vapor pressure of the sump water vapor pressure. The licensee also stated that NPSH cases were conducted for two limiting temperature cases, one at 212 °F and one at 60 °F. The licensee stated that even for the 60 °F case, the containment pressure was assumed to be the vapor pressure of the fluid.

The licensee stated that the NPSH required values were based on the vendor pump curves. It is assumed the licensee used the industry standard practice criterion of 3 percent degradation in pump head. Values of NPSH required for flows above 4,750 gpm (4,921 gpm) were extrapolated using the square of the flow ratio.

The licensee stated that the piping resistances were calculated using Fathom software with inputs coming from standard industry references and methods.

The licensee stated that the limiting single failure for the NPSH analysis is the failure of a single RHR pump after both pumps are switched to the recirculation mode. The higher flow from a single pump results in higher NPSH required and increases the suction piping losses. The single pump case also results in higher total strainer head loss because the CSHL component is significantly higher for the single pump case.

The licensee provided the minimum pump NPSH margins. Both cases were calculated for the LBLOCA. Both cases used the limiting case of single pump flow of 4,921 gpm, which is discussed above. The effects of potentially lower sump levels for the SBLOCA case are discussed above in this section. The margins are based on two cases. The 212 °F case used the sump level at the beginning of recirculation and resulted in an NPSH margin of 3.28 ft. The 60 °F case resulted in an NPSH margin of 4.26 ft. This case used the sump level based on additional injection from the CS pumps aligned to the RWST following swapover of the RHR pumps to the sump. Note that the 60 °F case does not credit any subcooling of the liquid, which is very conservative.

In the head loss and vortexing section, the NRC staff noted that the licensee estimated a maximum void fraction at the RHR pump suction of 0.17 percent. It was not clear that this was accounted for in the licensee's NPSH calculations. The NRC staff asked the licensee whether it accounted for the NPSH required ($NPSH_R$) adjustment due to void fraction as described in RG 1.82, Appendix A-3, or alternately how the effects of the void fraction on pump performance were evaluated. The licensee stated that the $NPSH_R$ was not adjusted to account for the void fraction that may occur at the pump suctions. The licensee stated that the void fraction is much lower than the limit in NEI 09-10, "Guidelines for Effective Prevention and Management of System Gas Accumulation," Revision 1, dated December 2010. The licensee also stated that conservatism was included in the void fraction analysis by using the maximum strainer head loss calculated at a low temperature and using the minimum strainer submergence. The licensee also did not credit void compression due to the increased fluid pressure as the fluid flows down to the pump suctions. The licensee stated that the pressure at the pump suction is 10 psi greater than that at the strainer. The NRC reviewed the licensee's response and reached the following conclusions regarding the evaluation. The guidance in NEI 09-10 states that it is concerned with gas accumulation in piping that may lead to transient conditions. It also addresses pump performance with respect to flow and developed head, but not $NPSH_R$. NEI 09-10 refers to NUREG/CR-2792, "An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions" (ADAMS Accession No. ML100110155) for gas intrusion conditions that are more steady state as would be expected with degasification due to strainer head loss. The guidance in NUREG/CR-2792 suggests using the same $NPSH_R$ correction for gas voids as the guidance in RG 1.82. The NRC staff agrees that there are unquantified conservatisms in the licensee's void evaluation. Any bubbles that form at the strainer will partially collapse due to the increased head at the pump suction. Additionally, some of the gases will likely become re-dissolved in the fluid. Also, the calculated amount of voiding was determined using conservative inputs. The head loss at the strainer was maximized to a high value, and the submergence of the strainer was minimized. These conservatisms combine so that the calculated void fraction is likely significantly greater than that which would occur in the plant. In addition, according to the guidance in NUREG/CR-2792, the $NPSH_R$ correction used in RG 1.82 is conservative. This is to ensure that ECCS and CSS pump operation will be conservatively evaluated with respect to void fraction and $NPSH_R$ and is necessary due to a lack of empirical data for this parameter. The NRC staff performed a calculation that assumed the conservatively calculated maximum void fraction at the strainer and found that the increase in $NPSH_R$ would not result in a reduction of NPSH margin to the extent that it would be negative. Considering the above, the NRC staff finds that the RAI response adequately demonstrates that void fraction would not have a significant impact on pump performance.

The NRC staff finds that the NPSH evaluation included significant conservatism. Therefore, even though some of the licensee's responses referred to information that was not fully applicable to the condition being evaluated, the NRC staff determined that the pumps taking suction from the ECCS sump would maintain adequate NPSH throughout their required response period following a LOCA.

NRC Staff Conclusion

For the NPSH area, the licensee has provided information such that the NRC staff has reasonable assurance that it has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the NPSH evaluation for Diablo Canyon 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 April 30, 2020.

The licensee provided the information requested in the content guide. The qualified and unqualified coating systems were listed in the April 30, 2020, submittal.

The licensee provided the assumptions related to coatings for debris transport. All coatings were assumed to enter the sump pool close to where they are applied. Unqualified coatings with unknown locations were assumed to be split evenly between upper and lower containment. The unqualified coatings in lower containment were assumed to be in the annulus, closer to the strainer. All coatings that were assumed to fail as fine particulate were assumed to transport without settling.

The licensee provided the surrogates used for head loss testing. Sil-Co-Sil (silica flour) was used as a surrogate for all qualified and unqualified coatings assumed to fail as fine particulate. The Sil-Co-Sil was stated to have a mean size distribution of about 10 microns. Acrylic paint chips were used as a surrogate for coatings that fail as chips. The chips were stated to be sizes ranging from 0.05 to 0.15 inches, which is finer than the chips predicted in the plant. The licensee stated that this was acceptable because finer debris is less likely to cause voids in the debris bed and reduce head loss. The licensee stated that the amounts of surrogates used were based on the volume that would be produced as debris. That is, the amount of surrogate used was corrected based on the ratio of the density of the surrogate to the actual coating. The NRC reviewed the surrogates used and finds them acceptable because they have characteristics that would result in realistic or conservative head loss in the debris bed. The use of smaller chips is acceptable because a filtering debris bed formed on the strainer and finer debris leads to higher head losses.

The licensee stated that it used a 4D ZOI for qualified coatings. This value is consistent with NRC guidance for qualified epoxy systems. This was justified for all qualified coatings because all inorganic zinc (which alone would have a ZOI of 10D) is topcoated with epoxy, and therefore, protected by the epoxy.

The licensee stated that not all items coated with qualified coating systems were included in the computer aided design model that was used to calculate the coating debris term. Therefore, 20 percent was added to the steel coatings term to account for these items. The licensee stated that this was conservative based on experience from the PWR fleet. The NRC staff concludes that this assumption is reasonable based on industry experience.

Unless otherwise justified, the unqualified coatings were assumed to fail as fine particulate. The unqualifed systems that testing demonstrated would fail as chips (similar to degraded qualified epoxy) were treated appropriately. The chip characteristics are discussed above in this section. Treatment of the coatings as particulate is acceptable because a filtering bed was established during head loss testing and particulate in the debris bed causes higher head loss than chips.

The licensee described its containment coatings assessment program. It stated that there are two procedures that control the containment coatings. One procedure is for coatings work and the other is for inspections. The licensee stated that both procedures refer to the containment coatings specification, which incorporates ANSI N 101.2, "Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities," as a basis. The licensee stated that the coatings are inspected each outage by a qualified inspector. If degraded conditions are discovered, they are documented in the corrective action program. Repairs are scheduled based on an evaluation. Coatings that remain unqualified are tracked by the site. The NRC staff finds that the licensee's coating assessment program is consistent with the coatings review guidance, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Coatings Evaluation," dated March 2008 (ADAMS Accession No. ML080230462).

NRC Staff Conclusion

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the coatings evaluation for Diablo Canyon 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 July 10, 2008.

The licensee identified the significant design, administrative, 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. The NRC staff determined that the station controls and practices implemented are adequate to maintain the assumed debris source term. The licensee revised procedures to require an assessment of potential effects of modifications on the recirculation function. The licensee established an insulation database to ensure that maintenance activities do not change the analysis assumptions without adequate evaluation. The licensee reviewed its procedures, programs, and design requirements to identify areas that require controls to prevent changes to assumptions in the sump analyses.

The licensee also established containment cleanliness programs and added specific instructions to activities for cleaning containment. Aggressive cleaning of the containment including vacuuming has been implemented. Containment cleanup is scheduled for later in outages to reduce the amount of debris that may be left in the containment. The licensee also includes training on the importance of containment cleanliness in its General Employee Training.

Once the containment cleanup has been completed, the licensee uses material exclusion procedures to verify that activities do not leave potential debris sources behind. In addition, following power entries, a visual inspection is performed and any foreign material is removed.

The licensee maintains a coatings program to ensure that coatings are inspected and repaired as necessary. Coating issues are entered into the site corrective action program to establish extent of condition, and the necessary actions to ensure that the coatings are maintained in acceptable condition.

The licensee created an engineering document that includes the inputs and assumptions for debris generation, transport, head loss, chemical effects, upstream and downstream effects, and associated testing to enable site personnel to easily refer to these aspects of the evaluation.

The licensee provided all the information requested in GL 2004-02 and the associated NRC staff guidance. The NRC staff finds that Diablo Canyon has enhanced its debris source term program in a way that provides reasonable confidence that the debris source term in containment will be consistent with the assumptions used in the GL 2004-02 evaluation.

NRC Staff Conclusion

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed so that the assumptions and inputs for the associated evaluations will be maintained. Therefore, the NRC staff concludes that the debris source term evaluation for Diablo Canyon is acceptable. The NRC staff considers this item closed for GL 2004-02.

## 12.0 SCREEN MODIFICATION PACKAGE

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

### NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through July 10, 2008.

The licensee provided a basic description of the major features of the new sump strainers and associated changes to the plant. The strainers are a General Electric passive design and are installed in the containment annulus outside the crane wall. The strainer supplies both RHR pump suction lines. The strainer has 3,276.5 $ft^2$ of surface area resulting in an approach velocity of about 0.00552 feet per second for a two pump operation.

There are front and rear strainer sections connected by a plenum. The front and rear strainers consist of vertically oriented perforated plates with 3/32-inch perforations. The strainer is constructed of stainless steel. A trash rack and debris curb prevent large debris from reaching the strainer.

The licensee provided a basic description of the associated modifications to remove/relocate interferences and protect the new sump strainers.

The screen modification package area was adequately addressed and provided the required information. The description provided a good basic understanding of the new strainer location, configuration, and construction details.

### 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 Diablo Canyon is acceptable. The NRC staff considers this item closed for GL 2004-02.

## 13.0 SUMP STRUCTURAL ANALYSIS

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

### NRC Staff Review

The NRC staff's review is based on Section 3k, "Sump Structural Analysis," of the licensee's July 10, 2008, submittal. The guidance documents used for the review include the Revised Content Guide from November 2007 and RG 1.82.

The NRC staff review has led to the conclusion that the licensee has adequately addressed the information requested by the Revised Content Guide for GL 2004-02 Item 2(d) (vii). The licensee's submittal stated that separate finite element models (employing ANSYS computer software) were developed for the trash rack, front strainer assembly, and rear strainer assembly. The structural models were subjected to bounding loading combinations consisting of dead weight, debris weight, hydrostatic loads, design basis earthquake loads, and thermal loads. The analysis results for each of the three assemblies meet the applicable, allowable stress requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, 1989 Edition, Subsections NC, ND, NF, NG, and Appendix F. These results include the qualification of welds and fasteners. Furthermore, the design and analysis of the anchor bolts were shown to meet the manufacturer recommended allowable stresses and Diablo Canyon requirements. The resulting stress margins for the strainer components varied from 5.27 to 1.03, and all were within allowable limits (i.e., stress margin greater than 1.0).

In order to address the potential of dynamic effects on the strainer modules due to a HELB, the licensee stated that the entire strainer assembly is inside the annulus area of Containment. The location is such that it is not subject to loading from pipe whip, jet impingement, or missile impact.

The licensee's submittal stated that no credit was taken for a backflushing strategy.

The information provided by the licensee shows that the sump structural evaluation contains inherent conservatism by complying with the design code of record. All stress margins were stated to be within the allowable limits and above the limit of 1.0. Impacts due to a HELB are not applicable due to the location of the strainer in Containment, and the licensee does not take credit for a backflushing strategy. The licensee has provided sufficient information to show that a level of conservatism exists and the intent of the Revised Content Guide for GL 2004-02 Item 2(d) (vii) has been met.

NRC Staff Conclusion

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

## 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 July 10, 2008.

The licensee stated that an evaluation of flowpaths necessary to return water to the recirculation sump strainer was performed in accordance with the recommendations contained within NEI 04-07. The main purpose of the evaluation was to identify locations where the holdup of water could occur. This evaluation identified architectural or equipment features that should be evaluated when calculating the minimum containment water level due to the potential for water holdup. Holdup volumes were calculated for the refueling cavity drain, ductwork, curbs, and other features that could hold up water. The holdup analysis was also considered whether debris generation and debris transport could create additional holdup volumes due to blockage of the flowpaths.

The major flowpaths that return water to the containment sump are the refueling canal drains, stairwells, and the openings in the crane wall. The licensee stated that the refueling canal drain for each unit is an 8-inch opening protected by an 8-inch tall basket with openings about 4-inches square. The licensee stated that the openings are large enough to prevent debris from blocking this drain line. An equipment laydown area in the refueling canal is slightly recessed below the rest of the refueling canal floor. The volume of this space was calculated to holdup approximately 244 cubic feet of inventory, which is not credited for the minimum containment water level. The licensee stated that the crane wall doors were modified to make them less susceptible to blockage from debris. The NRC has identified the refueling canal as an area that has the potential to hold up a large amount of sump inventory. The NRC staff finds that the Diablo Canyon modification to the refueling canal drain has reasonable assurance to prevent blockage of the drain.

NRC Staff Conclusion

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

## 15.0 DOWNSTREAM EFFECTS - COMPONENTS AND SYSTEMS

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

NRC Staff Review

The NRC staff review is based on documentation provided by the licensee through April 30, 2020.

The licensee stated that it performed the ex-vessel downstream effects evaluation in accordance with the NRC approved WCAP 16406-P-A, Revision 1, and the associated NRC SE. The licensee used conservative assumptions for debris transport to the downstream components.

The evaluation identified that seal leakage from the ECCS pumps could increase slightly due to wear. The licensee enhanced an existing procedure to address the potential for post-LOCA recirculation loop leakage external to the containment. The changes provide steps to identify and isolate leakage in these components. A new operating procedure was developed to allow isolation of a train of ECCS if it is required.

The evaluation results show that the required core cooling can be maintained without any modifications to plant equipment. Only the procedure changes described above were required. Because the licensee performed ex-vessel downstream effects calculations and analyses in accordance with the NRC recognized methods prescribed in WCAP-16406-P-A, Revision 1, and the associated NRC SE, including limitations and conditions, the NRC staff concludes that the downstream effects of debris laden recirculated sump fluid on ex-vessel downstream components and systems has been adequately addressed at Diablo Canyon.

NRC Staff Conclusion

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

## 16.0 DOWNSTREAM EFFECTS - FUEL AND VESSEL

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

NRC Staff Review

The licensee stated that the in-vessel downstream effects were evaluated per TR WCAP-16793-NP (original TR for in-vessel) and the associated staff SE, and WCAP-17788-P, Revision 1, "Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090)" (ADAMS Package Accession No. ML20010F181), and the associated NRC review guidance on in-vessel effects. Diablo Canyon evaluated peak cladding temperature and deposition thickness of debris on the fuel rod using the older TR. The evaluation of debris accumulation in the core was evaluated in accordance with the NRC staff guidance that is based in the newer TR. The licensee stated that the evaluation showed that LTCC will not be inhibited by debris injected into the core during recirculation.

The licensee stated that they performed plant-specific testing to determine the amount of fiber that could penetrate the strainer at the same time that strainer head loss testing was performed. The testing was conducted using conservative conditions, and the configuration and procedures used were the similar to those for head loss testing. For debris, only fine fiber was used, and it was batched into the test slowly. Debris was captured downstream of the strainer in 5-micron filter bags. The amount of fiber that bypassed the strainer was determined by weighing the bags before and after debris capture.

The results of the testing were used to quantify the bypass that could occur at plant conditions. The licensee stated that CS flow was minimized when calculating the amount of fiber that could reach the core inlet. The NRC staff reviewed the testing and the use of test results and finds that the methods are acceptable because they would result in realistic or conservative amounts of debris arriving at the core.

The licensee used Option 4 of the NRC review guidance on in-vessel effects and provided a summary table of the results of its evaluation. The NRC guidance directs the licensee to compare plant-specific values for important parameters to bounding values of the same parameters. The bounding values were developed in TR WCAP-17788. The licensee stated that all parameters for Unit 2 are bounded by the TR. For Unit 1, the licensee stated that all values were bounded except thermal power, which is about 16 percent higher than the value analyzed in the TR. The analyzed downflow plant in the TR was a three-loop Westinghouse plant with a smaller reactor core and lower rated thermal power level.

The NRC staff noted that the minimum safety injection flow rate per fuel assembly is about 4 percent lower than the analyzed value for both units.

The licensee stated that even though the thermal power for Unit 1 is higher than the value analyzed in the TR, adequate LTCC would be maintained. The basis for this conclusion is that the thermal power level on a per-fuel-assembly basis remains bounded by the analyzed plant. The licensee also noted that the earliest recirculation from the containment sump starts in 24.9 minutes while the analyzed value for the initiation of recirculation was 20 minutes. The additional 4.9 minutes allows decay heat to decrease prior to the potential delivery of debris to the core (and begin increasing resistance to flow through the core inlet). The licensee noted that the NRC staff guidance stated that an increase in earliest recirculation time from 20 to 23 minutes significantly decreases the potential for a debris-induced core uncover and heatup. This is because of the reduction in decay heat that occurs during this time.

The licensee stated that the maximum amount of fiber that could arrive at the core inlet is less than the limit analyzed in the TR. The licensee stated that the smaller fiber load is associated with a significantly reduced flow resistance at the core inlet. The licensee cited NRC staff guidance that concluded that the fiber accumulation at the core inlet would be non-uniform further reducing the core inlet resistance. The licensee also stated that chemical precipitation would not occur prior to the swapover to hot-leg recirculation, which bypasses the core inlet and any fiber accumulation.

The NRC staff considered the following in its review of the Diablo Canyon evaluation for LTCC.

- For Unit 1, the analyzed downflow plant is a three-loop plant. The analyzed power density is 18.8 megawatt (MW)/fuel assembly, whereas Diablo Canyon's power density is about 17.8 MW/fuel assembly. Even though the analyzed thermal power level is lower than the plant power level, it scales closely to the plant's per-fuel-assembly power density.

- For both units, the licensee noted that the lowest fuel assembly flow is about 4 percent lower per fuel assembly that the lowest value analyzed. Compensating for that, there is a 4.9-minute delay in sump swapover time relative to what was analyzed, in conjunction with the fact that the plant per-fuel assembly debris amount is significantly lower than analyzed for the Westinghouse fuel assembly. These two considerations suggest that, even with the lower-than-analyzed safety injection flow per fuel assembly, a debris bed substantial enough to cause core uncovery would be unlikely to form, and if it were, the decay heat would be lower than analyzed, suggesting that the Diablo Canyon results would be less severe than predicted in the WCAP-17788, Volume 4, analyses.

The NRC staff reviewed the licensee's evaluation and agreed that these factors provide adequate assurance that resistance at the core inlet will not inhibit flow and LTCC will be maintained.

The NRC staff requested that the licensee provide the chemical effects test group number from Volume 5 of WCAP-17788-P that was used in its in-vessel evaluation and verify that the test is representative of the plant-specific conditions. The licensee responded in its response to RAIs by letter dated April 15, 2021 (Question 6), that WCAP-17788 Test Group 45 was applied as representative of the Diablo Canyon post-LOCA conditions. The licensee stated that the test group demonstrates that the minimum chemical precipitation time is greater than 24 hours. The licensee also provided tables comparing scaling of the test conditions to the plant-specific conditions. The NRC staff determined that Test Group 45 adequately represented the Diablo Canyon post-LOCA conditions for the purpose of evaluating in-vessel chemical formation timing. The NRC staff finds the absence of chemical precipitation during the 24-hour test duration supports LTCC since hot leg recirculation and other alternate flow paths will provide adequate cooling if chemical precipitates do not form until 24 hours after a LOCA.

The licensee provided information regarding peak cladding temperature and the deposition thickness for debris that could accumulate on the fuel rods in the reactor vessel. The evaluations were performed per WCAP-16793-NP. The licensee calculated a peak cladding temperature of about 365 °F and a deposition thickness of about 20 mils. These values are significantly lower than the acceptance criteria of 800 °F and 50 mils. In its recent guidance for in-vessel evaluations, the NRC staff did not request licensees to provide this information. However, the NRC reviewed the licensee evaluation and determined that it was performed per previous NRC staff guidance and showed acceptable results.

NRC Staff Conclusions

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

## 17.0 CHEMICAL EFFECTS

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on strainer head loss. Chemical effects related to the reactor vessel (i.e., in-vessel) were discussed in Section 16.0 above.

NRC Staff Review

The NRC staff reviewed the information related to chemical effects that was contained in the licensee submitted documents previously identified in Section 1.0 above. The reference documents used for this review include the March 31, 2008, NRC staff SE of WCAP-16530-NP-A, and NRC staff guidance, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant-Specific Chemical Effects Evaluations," dated March 2008 (ADAMS Accession No. ML080380214).

The licensee uses sodium hydroxide for post-LOCA pool pH control in Diablo Canyon. Depending on postulated break conditions, the post-LOCA equilibrium sump pH was determined to range from 8.0 to 9.5. The licensee has replaced the sump strainers in both units with General Electric disk type passive strainers to increase the available strainer area to approximately 3,000 $ft^2$ per unit.

The licensee's plant-specific debris generation and transport analyses determined that the debris sources considered in the chemical effects analysis for Diablo Canyon includes latent E-glass fiber and FOAMGLAS, other E-glass (e.g., Temp-Mat), Kaowool and Mica aluminum silicate, Cal-Sil insulation and coatings (i.e., metallic aluminum paint).

The overall chemical effects strategy for Diablo Canyon included:

- Calculating the quantity of chemical precipitates using the WCAP-16530-NP-A methodology.
- Introducing the pre-mixed precipitates into prototypical strainer disk testing.
- Applying a solubility equation to determine the maximum precipitation temperature.
- Time based determination of acceptable head losses.

*Chemical Precipitate Calculation*

The licensee's chemical effects test for Diablo Canyon, as detailed in its April 30, 2020, letter, was based on the WCAP-16530-NP-A methodology using plant-specific inputs. The WCAP methodology involves determining the chemical precipitate load, preparing the calculated amount of precipitates, and adding the pre-mixed precipitates to the test loop after a debris bed is formed on the test strainer and the head loss is stable. The NRC staff has accepted the WCAP-16530-NP-A approach for calculating the quantity of chemical precipitate to add to strainer testing.

For Diablo Canyon, the plant unsubmerged aluminum exposed to CS is 1,100 $ft^2$, and the submerged aluminum is 525 $ft^2$. Both aluminum area values include contingency. These values do not include aluminum paint, which were calculated separately and vary depending on break location. The licensee did not credit solubility of aluminum when calculating the quantity of aluminum precipitates. The results of the WCAP-16530-NP-A chemical precipitate calculations were provided in terms of total aluminum precipitated that ranged from 198 lbm to 231 lbm for the break cases evaluated.

*Testing*

In 2016, the licensee performed updated strainer head loss testing at Alden Research Laboratory, Inc. (Alden). The licensee's integrated head loss testing in the flume at Alden included the evaluation of chemical precipitates. The Alden facility included a test flume, pumps, test strainer sections, instrumentation and controls, chemical mixing tanks, and associated piping needed to perform testing. The test strainer module had a surface area of 340.2 $ft^2$ and was a full-scale section of the strainer modules installed in the Diablo Canyon containments. The test conditions (flow-rate and debris quantities) were scaled down based on the surface of the strainer module adjusted for the sacrificial surface area. The strainer test added the WCAP-16530-NP-A predicted aluminum precipitate as aluminum oxyhydroxide. This is acceptable to the NRC staff as discussed in the SE for WCAP-16530-NP-A (see page 16 of the SE). The licensee performed sump strainer testing and simulated chemical effects by adding pre-mixed precipitate once the conventional debris bed was established on the strainer and head loss was stable. The NRC staff is very familiar with the licensee's test and evaluation methods for strainer testing since the NRC staff has visited the Alden test facilities and observed testing multiple times between 2005 and 2016.

Chemical Effects Summary

The Diablo Canyon chemical effects evaluation made a number of conservative assumptions that resulted in a bounding amount of calculated chemical precipitates. For example, the amount of aluminum release was calculated using the maximum sump temperature profile during recirculation which results in greater aluminum release. The licensee inputs for chemical precipitates assumed the maximum possible pH of 9.5 for aluminum release and the maximum length of CS time, which resulted in a maximum amount of aluminum release. For chemical effects purposes only, the licensee assumed recirculation started at 53 minutes, which results in a higher pH spray for a longer period and also increases aluminum release.

Diablo Canyon credits aluminum solubility in its plant specific analysis using the solubility relationship developed by Argonne National Laboratory (see ADAMS Accession No. ML091610696). For the plant specific solubility calculations, the licensee assumed a conservative sump pH of 7.5, which results in significantly lower solubility than the lowest projected sump pH of 8.0. The licensee also assumed precipitation occurs at 180 °F although, the highest precipitation temperature for the cases evaluated was 173 °F. The NRC staff finds the use of the Argonne National Laboratory equation to determine solubility acceptable since it has been demonstrated to be conservative at the 7.5 pH value assumed by the licensee.

The NRC staff finds the overall chemical effects evaluation for Diablo Canyon acceptable since an NRC-approved WCAP-16530-NP-A methodology was used to calculate the plant-specific chemical precipitate and prepare the chemical precipitate load that was added into the licensee's integrated head loss tests. The not-physically possible assumed combination of 7.5 pH for aluminum solubility and 9.5 pH for aluminum dissolution provides substantial conservatism in the Diablo Canyon overall chemical effects analysis. The licensee used the WCAP-16530-NP-A base model with one refinement related to aluminum solubility that is acceptable to the NRC staff. The licensee also addressed the chemical effects related RAI in its letter dated April 30, 2020. The RAI response was acceptable, which was previously discussed in Section 16.

NRC STAFF CONCLUSION:

For the chemical effects review area, the licensee has provided sufficient information such that the NRC staff has reasonable assurance that chemical effects have been addressed conservatively or prototypically for Diablo Canyon. Therefore, the NRC staff concludes that the chemical effects evaluation for Diablo Canyon 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 licensee provided a copy of changes made to the Diablo Canyon Final Safety Analysis Report to document the licensing basis regarding the effects of debris on recirculation. The NRC staff reviewed the changes and finds that they reflect the updated licensing basis as described in the licensee's submittals.

NRC Staff Conclusion

For this review area, the licensee has provided information, such that the NRC staff has reasonable assurance that the subject review area has demonstrated that the licensing basis is adequately documented. Therefore, the NRC considers this item closed for GL 2004-02.

## 19.0 CONCLUSION

The NRC staff has reviewed 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, GL 2004-02 requested addressees to perform an evaluation of the ECCS and CSS recirculation and, if necessary, take additional action to ensure system function in light of the potential for debris to adversely affect LTCC. The NRC staff finds the information provided by the licensee demonstrates that debris will not inhibit the ECCS or 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 the licensee's responses to GL 2004-02 are adequate and considers GL 2004-02 closed for Diablo Canyon.

Principal Contributors: S. Smith
A. Russell

Date: July 29, 2021

SUBJECT: DIABLO CANYON NUCLEAR POWER PLANT, 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 JULY 29, 2021

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