Enclosure 3

Callaway Methodology for a Risk-Informed Approach to Address Generic Letter 2004-02

ATTACHMENTS:

Attachment 3-1

Introduction

This enclosure provides the Callaway methodology for a risk-informed approach to respond to Generic Letter (GL) 2004-02, as discussed in Staff Requirements Memorandum (SRM)-SECY-12-0093, "Closure Options for Generic Safety Issue - 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance". The risk-informed approach is intended to be applied to Callaway Nuclear Plant Unit 1.

In the Risk over Deterministic (RoverD) methodology, the effects of debris that are bounded by plant-specific testing are mitigated in accordance with NRC-accepted methodology for resolution of GL 2004-02. Breaks that are not bounded by plant-specific testing are conservatively assumed to result in core damage. RoverD addresses the effects on long-term cooling due to debris accumulation on the emergency core cooling system (ECCS) and containment spray system (CSS) sump strainers in recirculation mode as well as core flow blockage due to in-vessel effects of debris that penetrates the strainers. A full spectrum of postulated loss-of-coolant accidents (LOCA) is analyzed, including double-ended guillotine breaks for all pipe sizes up to the largest pipe in the reactor coolant system. The changes to core damage frequency and large early release frequency associated with GL 2004-02 concerns are quantified by applying the LOCA frequencies published in NUREG-1829, and then compared to Regulatory Guide (RG) 1.174 acceptance guidelines. The results quantified in Section 7 of Enclosure 3-3, in combination with the defense-in-depth and safety margin described in Enclosure 3-4, meet the criteria of RG 1.174 for considering the risk from effects of LOCA debris to be in Region III (very small) and that no additional plant modification is required to close GL 2004-02 for Callaway. A detailed description of the RoverD methodology is presented in Enclosure 3-3 of this submittal.

The licensing basis with regard to effects of debris is that there is a high probability that the effects of LOCA debris will be mitigated based on successful plant-specific prototypical testing, and analyses that show that the risk from breaks that could generate debris that is not bounded by the testing is very small and acceptable in accordance with the criteria of RG 1.174.

The regulations require a deterministic analysis. Implementation of the licensing basis requires justification in accordance with 10 CFR 50.12 of exemptions to the relevant regulations; i.e. 10 CFR 50.46(a)(1), General Design Criteria (GDC) 35, GDC 38 and GDC 41. The exemptions are complemented by an amendment to the Callaway Unit 1 Operating License to allow for the change in analysis methodology per 10 CFR 50.59 and to change ECCS and CSS Technical Specifications.

Attachment 3-2

Deterministic Basis -
Generic Letter 2004-02 Supplemental Response

Deterministic Basis - Generic Letter 2004-02 Supplemental Response

Subject: Union Electric Company's (d.b.a. Ameren Missouri) approach to resolving issues described in Generic Letter (GL) 2004-02 is to use the guidance and requirements of NEI 04-07 (Reference [1]), industry guidance, industry and plant-specific tests, and the South Texas Project Pilot Plant's use of Risk over Deterministic (RoverD) methodology to perform a comprehensive set of evaluations of the effects of design-basis accident conditions on the ability of structures, systems, and components, including the containment emergency sump strainers, to mitigate the consequences of the analyzed accidents and maintain long-term core cooling in a manner consistent with governing regulatory requirements listed in GL 2004-02. This Enclosure 3 provides the Callaway methodology for risk-informed approach and responds to GL 2004-02. All responses provided within this document supersede any responses that were previously submitted unless otherwise denoted.

1 Overall Compliance

Provide information requested in GL 2004-02 Requested Information Item 2(a) regarding compliance with regulations.

GL 2004-02 Requested Information Item 2(a)

Confirmation that the ECCS and CSS recirculation functions under debris loading conditions are or will be in compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this GL. This submittal should address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made and this licensing basis has been updated to reflect the results of the analysis described above.

Response:

This submittal by Ameren Missouri proposes a change associated in methodology to use a risk-informed approach to determine the design requirements to address the effects of loss-of-coolant accident (LOCA) debris instead of a traditional deterministic approach. The details of the risk-informed approach are provided in Attachment 3-3. The debris analysis (which includes coatings, insulation and other debris) covers a full spectrum of postulated LOCAs, including double-ended guillotine breaks (DEGB), for all pipe sizes up to and including the design basis accident (DBA) LOCA to provide assurance that the most severe postulated LOCAs are evaluated. While a deterministic licensing basis will continue to apply to LOCA break sizes that generate debris that is bounded by Callaway plant-specific testing, Callaway conservatively relegates to failure the LOCA break sizes that can generate and transport debris not bounded by the Callaway plant-specific testing and applies the risk-informed methodology. Callaway's RoverD methodology applies NUREG-1829 to determine the break frequency for the smallest breaks that fail to obtain the highest frequency, and uses that frequency as the change in core damage frequency (ΔCDF) for comparison to the criteria in Regulatory Guide (RG) 1.174. The results of the evaluation show that the risk from the proposed change is "very small" in that it is in Region III of RG 1.174. The methodology includes conservatisms in the plant-specific testing and in the assumption that all the unbounded breaks are relegated to failure.

Callaway's risk-informed approach to the effects of LOCA debris replaces the existing deterministic approach described in Callaway's licensing basis and consequently requires an amendment to the Callaway Unit 1 Operating License to incorporate the revised methodology per the requirements of 10 CFR 50.90. This proposed amendment to the Operating License is described in Enclosure 2. The proposed methodology changes to implement and replace the current deterministic methodology with a risk-informed methodology also require changes to the descriptions of how

Callaway meets 10 CFR 50.46(a)(1), GDC 35, GDC 38 and GDC 41. Those changes require exemptions to certain requirements of 10 CFR 50.46(a)(1), GDC 35, GDC 38 and GDC 41, and the requests for the exemptions are provided in Attachments 1-1 through 1-4 of this submittal.

In addition, Ameren Missouri proposes to amend the Callaway Unit 1 Operating License to revise the Technical Specifications (TS) for the ECCS and containment spray system (CSS). The changes proposed for these TS would delete Surveillance Requirement (SR) 3.5.2.8 in TS 3.5.2, "ECCS – Operating," and delete its mention from SR 3.5.3.1 in TS 3.5.3, "ECCS - Shutdown," add TS 3.6.8, "Containment Recirculation Sumps," and clarify TS 5.5.15, "Safety Function Determination Program." The proposed TS changes will align the TS with the risk-informed methodology change and follow the TSTF-567 Model. The proposed actions are based on the amount of debris tested in the Callaway plant-specific testing so that the determination of operability is performed without needing a risk assessment, which makes the process consistent with NRC guidance on operability determinations. The License Amendment Request (LAR) for the changes to the TS is provided in Enclosure 2.

Ameren Missouri previously replaced the sump screens in Callaway Unit 1 with substantially larger and physically more robust strainers; therefore, there are no physical modifications needed or planned in support of this application.

When implemented, the licensing basis with regard to effects of debris is that there is an acceptably high probability that the effects of LOCA debris will be mitigated based on successful plant-specific prototypical testing using deterministic assumptions, and analyses that show that the risk from breaks that could generate debris that is not bounded by the testing is very small and acceptable in accordance with the criteria of RG 1.174.

2 General Description of and Schedule for Corrective Actions

Provide a general description of actions taken or planned, and dates for each. For actions planned beyond December 31, 2007, reference approved extension requests or explain how regulatory requirements will be met as per Requested Information Item 2(b). (Note: All requests for extension should be submitted to the NRC as soon as the need becomes clear, preferably not later than October 1, 2007.)

GL 2004-02 Requested Information Item 2(b)
A general description of and implementation schedule for all corrective actions, including any plant modifications, that you identified while responding to this GL. Efforts to implement the identified actions should be initiated no later than the first refueling outage starting after April 1, 2006. All actions should be completed by December 31, 2007. Provide justification for not implementing the identified actions during the first refueling outage starting after April 1, 2006. If all corrective actions will not be completed by December 31, 2007, describe how the regulatory requirements discussed in the Applicable Regulatory Requirements section will be met until the corrective actions are completed.

The information in this section supplements information previously provided by Ameren Missouri in response to GL 2004-02, section 2, Requested Information Item 2(b) (Reference [2]). This response now introduces testing completed in 2016 which replaces 2008 testing meant to support assumptions and corresponding conclusions contained in the earlier GL 2004-02 response.

Response:

Other than the implementation of the proposed changes to the TS and Final Safety Analysis Report (FSAR) associated with the LAR included in this application, Ameren Missouri does not anticipate implementation of any additional modifications to Callaway Unit 1 in response to GL 2004-02 based on the data collected and analysis performed to date.

This response supplements the plant modifications described in this response in the previous submittal (Reference [2]).

3 Specific Information Regarding Methodology for Demonstrating Compliance

Specific information regarding methodology is necessarily two-fold: deterministic and risk-informed. Compliance is demonstrated using 2016 deterministic testing results with further risk-informed RoverD analysis.

3.a. 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.

1. *Describe and provide the basis for the break selection criteria used in the evaluation.*
2. *State whether secondary line breaks were considered in the evaluation (e.g., main steam and feedwater lines) and briefly explain why or why not.*
3. *Discuss the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance.*

Response to 3.a.1. Describe and provide the basis for the break selection criteria used in the evaluation:

A wide range of hypothetical pipe break (location and size) cases at Callaway were evaluated. The risk assessment utilized Containment Accident Stochastic Analysis GSI Resolution and Evaluation (CASA Grande) software over a wide range of potential break sizes and break locations in conjunction with the Callaway CAD model to determine bounding accident scenarios that may pose a threat to plant operation in the event of a DBA. Debris sources that are not break-dependent, such as latent debris and unqualified coatings debris, were also evaluated.

CASA Grande automates zone of influence (ZOI) debris generation and analyzes each weld location for DEGB spherical ZOI destruction, as well as partial-break hemispherical ZOI destruction. Fiber debris generation at each location and for each break size is found with the convergence criteria discussed in Attachment 3-3. Since all Class 1 weld locations are analyzed for various break sizes there is no need for break selection criteria. Note that secondary line breaks, spurious and stuck-open pilot-operated relief valves, and pump seal LOCAs were also assessed.

Response to 3.a.2. State whether secondary line breaks were considered in the evaluation (e.g., main steam and feedwater lines) and briefly explain why or why not:

Secondary line breaks (large main steam and feedwater line breaks) were considered as secondary risk contributors. Refer to the responses to Questions 34 and 35 in Enclosure 5 for additional information regarding secondary risk contributor screening.

Based on the screening results, there is no contribution to ΔCDF/LERF associated with GL 2004-02 phenomena from secondary line breaks

Response to 3.a.3. Discuss the basis for reaching the conclusion that the break size(s) and locations chosen present the greatest challenge to post-accident sump performance:

Because the CASA Grande computational debris generation modules analyze each Class 1 weld location for varying break sizes, all locations that present a challenge to post-accident sump performance are evaluated. Discussion of the CASA Grande results is provided in Attachment 3-3.

3.b. Debris Generation/Zone of Influence (ZOI) (Excluding Coatings)

The objective of the debris generation/ZOI process is to determine, for each postulated break location: (1) the zone within which the break jet forces would be sufficient to damage materials and create debris; and (2) the amount of debris generated by the break jet forces.

1. *Describe the methodology used to determine the ZOIs for generating debris. Identify which debris analyses used approved methodology default values. For debris with ZOIs not defined in the guidance report/SE, or if using other than default values, discuss method(s) used to determine ZOI and the basis for each.*
2. *Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent.*
3. *Identify if destruction testing was conducted to determine ZOIs. If such testing has not been previously submitted to the NRC for review or information, describe the test procedure and results with reference to the test report(s).*
4. *Provide the quantity of each debris type generated for each break location evaluated. If more than four break locations were evaluated, provide data only for the four most limiting locations.*
5. *Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.*

The information in this section revises information previously provided by Ameren Missouri to GL 2004-02, section 3.b. (Reference [2]).

Response to 3.b.1. Describe the methodology used to determine the ZOIs for generating debris. Identify which debris analyses used approved methodology default values. For debris with ZOIs not defined in the guidance report/SE, or if using other than default values, discuss method(s) used to determine ZOI and the basis for each:

The methodologies used by Callaway to determine debris generation ZOIs are:

1. For NUKON® and Thermal-Wrap®, Callaway implemented ZOIs consistent with the risk-informed, pilot plant. Proprietary report ALION-REP-ALION-2806-01, “Insulation Debris Size Distribution for use in GSI-191 Resolution,” (Reference [4]) provides a refined methodology to NEI 04-07 for calculating the distribution of NUKON® and Thermal-Wrap® debris sizes within the ranges of spherical ZOI volumes. Pressure values within an expanding jet decrease as the fluid travels away from the break point. The debris size distribution of destroyed insulation resulting from jet impingement is dependent on jet pressure and is therefore different at increased distances from the break location. The distances are classified in sub-zones that were determined using air jet impact test data (Reference [4]), with conservatism added to account for the potentially higher

level of destruction from a two-phase jet. Alion report 2806-01 (Reference [4]) shows that within the overall ZOI, the size distribution would vary based on the distance of the insulation from the break, and insulation debris generated near the break location would consist of more small pieces than would insulation debris generated near the edge of the ZOI.

2. Min-K insulation installed within the reactor cavity at Callaway cannot be destroyed from a HELB. The location of the Min-K panels is such that it cannot be impacted by HELB jets. As stated in staff comments (Reference [5]), "The NRC staff agrees that the test results only apply to Callaway and Wolf Creek Nuclear Plants and that these plants have performed plant-specific evaluations to determine that the Min-K panels cannot be impacted by the jet based on the insulation panel locations in the plant."

3. Alphamat D® blankets are installed at Callaway on the top of the reactor vessel similar to the location of Min-K insulation. These blankets are employed for high heat thermal protection within Callaway and a total quantity of 43.84 ft^3 was measured from plant drawings. Since Alphamat D® is in a similar location to Min-K, Alphamat D® cannot be destroyed from a HELB. Therefore, failure of Alphamat D® blankets is not considered.

4. FOAMGLAS® is located on the steam generator blowdown system and Residual Heat Removal (RHR) system. FOAMGLAS® was discovered in containment in the summer of 2019 and is not evaluated for debris generation. Approximately 146 ft^3 or 1167 lbm of FOAMGLAS® are in containment. In the analysis documented in this LAR, low density fiber glass (LDFG) is modeled at the location of FOAMGLAS®. This results in an over prediction of destroyed LDFG and risk, but an under prediction of destroyed particulate at break locations that have the potential to destroy FOAMGLAS®.

5. Transco RMI is used in containment as equipment insulation on the steam generators. Mirror RMI is used on the reactor pressure vessel head and reactor coolant system (RCS) on both the hot leg and cold leg piping. Both types of RMI are composed of stainless steel. ZOIs implemented for these types of RMI adhere to guidance in the NEI 04-07 Volume 2.

Response to 3.b.2. Provide destruction ZOIs and the basis for the ZOIs for each applicable debris constituent:

Destruction ZOI is defined as the volume about the break in which the jet pressure is greater than or equal to the destruction damage pressure of the insulation, coatings, and other materials impacted by the break jet. The size of the ZOI is defined in terms of pipe diameters of the piping assumed to break. The ZOI is defined as a spherical volume centered at the assumed piping break. Table 3.b-1 describes the destruction pressures and associated ZOI radii used in the evaluation of impacted Callaway materials.

Table 3.b-1: Destruction Pressure and ZOI Radii for Potential Debris Sources

Material	Destruction Pressure (psig)	ZOI	Reference
RMI-Mirror (with std. bands)	2.4	28.6	NEI 04-07, Vol. 2 SE Table 3.2
Transco RMI	114	2.0	NEI 04-07, Vol. 2 SE Table 3.2
Jacketed NUKON® (with std. bands)*	6	17.0	ALION-REP-ALION-2806-01 [4]
Thermal-Wrap®*	6	17.0	ALION-REP-ALION-2806-01 [4]
Min-K	N/A**	N/A**	Site-specific testing [6, 5]
AlphaMat D®	N/A**	N/A**	Site-specific testing [6, 5]

* Debris constituents and subshell ZOIs are not provided because this is proprietary information

** Encapsulated Min-K insulation is located near the reactor vessel and cannot be impacted by a ZOI (Reference [6, 5]). The same reactor vessel geometry that prevents Min-K insulation from being hit by HELB jet also applies to the Alpha D blankets installed in the same location.

Response to 3.b.3. Identify if destruction testing was conducted to determine ZOIs. If such testing has not been previously submitted to the NRC for review or information, describe the test procedure and results with reference to the test report(s):

Plant-specific destruction testing was conducted for Min-K. Min-K insulation installed within the reactor cavity at Callaway cannot be destroyed from a HELB. The location of the Min-K panels is such that it cannot be impacted by HELB jets. As stated in staff comments (Reference [5]), “The NRC staff agrees that the test results only apply to Callaway and Wolf Creek Nuclear Plants and that these plants have performed plant-specific evaluations to determine that the Min-K panels cannot be impacted by the jet based on the insulation panel locations in the plant.”

Plant-specific destruction tests that had been performed for jacketed NUKON® blankets as described in the previous submittal (Reference [2]) were not used to determine ZOIs. Destruction tests were not conducted for any other insulation to determine ZOIs. All ZOIs implemented, including Min-K, were previously reviewed by the NRC.

Response to 3.b.4. Provide the quantity of each debris type generated for each break location evaluated. If more than four break locations were evaluated, provide data only for the four most limiting locations:

CASA Grande postulates DEGB and multiple partial breaks at all ASME Class 1 and ISI weld locations, while also accounting for the weld break frequencies. DEGB and partial breaks are postulated at 704 locations. Table 3.b-2 shows the quantity of each debris type generated for the four most limiting locations.

Table 3.b-2: Maximum Insulation Debris Generated within the ZOI

Insulation	Weld 2-BB-01-3065D-WC-001-FW1	Weld EBB01D-RSG-INLET-SC010	Weld 2-BB-01-S402-2	Weld 2-BB-01-3065A-WDC-001-FW1
LDFG - Fine Pieces, lbm	243	243	241	241
LDFG - Small Pieces, lbm	811	809	809	843
LDFG - Large Pieces, lbm	374	374	374	325
LDFG - Intact Blankets, lbm	401	401	400	347
RMI - Small Pieces, lbm	48	49	28	49
RMI - Large Pieces, lbm	16	16	10	16
Min-K, lbm	0	0	0	0
Qualified Epoxy, lbm	23	21	53	6
Qualified IOZ, lbm	992	991	989	1000
Degraded Qualified, Fine, lbm	129	129	129	129
Degraded Qualified, Small Chip, lbm	25	25	25	25
Degraded Qualified, Large Chip, lbm	53	53	53	53
Degrade Qualified, Curled Chip, lbm	53	53	53	53
Rust, lbm	0	0	0	0
Unqualified Acrylic, lbm	31	31	31	31
Unqualified Alkyd, lbm	95	95	95	95
Unqualified Epoxy, lbm	2016	2016	2016	2016
Unqualified IOZ, lbm	2024	2024	2024	2024
Unqualified Varnish, lbm	18	18	18	18
Latent Particulate, lbm	170	170	170	170
Latent Fiber, lbm	30	30	30	30
Physical Fiber Margin, lbm	50	50	50	50

Response to 3.b.5. Provide total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment:

As shown in Table 3.b-3, the surface area for miscellaneous debris, consisting of signs / placards or equipment identification tags, labels and tape that remain in containment during power operation is 330.2 ft^2. To provide assurance that these miscellaneous debris quantities are not exceeded, walkdowns are conducted prior to the end of each refuel outage to ensure that unqualified temporary signs / placards are removed, and plant procedures require that new or replacement equipment identification tags or labels installed in containment to approved types that have been qualified as not contributing to transportable debris in the containment postaccident environment.

In addition to the metal equipment tags listed in Table 3b-3, a limited quantity of 3-in by 6-in EPRI radiological stainless steel tags are also in containment. These metal equipment and survey location tags were demonstrated to be nontransportable during 2016 testing.

Actions taken to mitigate the possibility of materials being inadvertently left behind in containment during maintenance are summarized in the responses to 3.i.1 and 3.i.2.

Table 3b-3. Miscellaneous Debris Area

Debris Type	Unit Area (in^2)	Unit Quantity	Total Area (ft2)
Tape	2" x 4"	45	2.5
Tape	2" x 10"	5	0.7
Fasteners	0.5" x 2"	90	0.6
Fasteners	1" x 5"	10	0.3
Personnel Protective Equipment	2" x 2"	50	1.4
Metal Equipment Tags (ZOI)	3" x 5"	2363	246.1
Bakelite Equipment Tags (ZOI)	2.5" x 1"	225	3.9
Taped Equipment Labels (ZOI)	2" x 7"	656	63.8
Bakelite Equipment Tags (outside ZOI)	2.5" x 1"	625	10.9
Total			330.2

3.c. Debris Characteristics

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

1. *Provide the assumed size distribution for each type of debris.*
2. *Provide bulk densities (i.e., including voids between the fibers/particles) and material densities (i.e., the density of the microscopic fibers/particles themselves) for fibrous and particulate debris.*
3. *Provide assumed specific surface areas for fibrous and particulate debris.*
4. *Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance.*

The debris characteristics determination process generally conforms, with some exceptions described below, to Sections 3.4.3 of NEI 04-07, Vol. 2 SE (Reference [1]).

The debris sources for Callaway include insulation, coatings, and latent debris. The insulation debris types discussed here include Alphamat D®, Min-K, NUKON®, Thermal-Wrap®, stainless steel RMI, and FOAMGLAS®. Due to their location in containment, Min-K and Alphamat D® insulation cannot be destroyed by a break jet, and are excluded from discussion. NUKON® and Thermal-Wrap® are located on various piping and equipment throughout containment. RMI is located on the steam generators, reactor vessel, and in the reactor bioshield penetrations on the hot and cold legs. A small quantity of FOAMGLAS® is located on portions of the steam generator blowdown system and RHR system. FOAMGLAS® was discovered in the summer of 2019 and was not explicitly analyzed. As noted in the response to 3.b.1, LDFG is modeled at the location of FOAMGLAS®. This results in an over prediction of destroyed LDFG and risk, but an under prediction of destroyed particulate at break locations that have the potential to destroy FOAMGLAS®.

Response to 3.c.1. Provide the assumed size distribution for each type of debris:

Fiber Debris

A four category size distribution assigned for LDFG is used in debris generation and transport analyses. The size distributions for debris inside the ZOI or a postulated break are taken from proprietary Alion Science and Technology's internal debris size calculation (Reference [4]). These sizes are based on the air jet impact test information presented in Appendix VI of the NEI 04-07 Vol. 2 SE (Reference [1]). Note, the Alion LDFG debris size distributions were reviewed and found acceptable by the NRC in deterministic resolutions, such as the "Indian Point Energy Center

Corrective Actions for Generic Letter 2004-02" (ML082050433) document (Reference [7]) and the risk-informed pilot plant.

Due to the location in containment, Min-K insulation cannot be destroyed by a break jet, and are thus excluded from this discussion (Reference [5]). Alphamat D® is in a similar location to Min-K. Therefore, Alphamat D® insulation cannot be destroyed by a break jet, and are thus excluded from this discussion.

<u>Non-Fiber Debris</u>

Based on Table 3-3 of NEI 04-07 Vol. 2 (Reference [1]), all types of RMI within a ZOI are expected to fail as 75% small pieces and 25% large pieces. Small pieces are defined as any RMI debris less than 4 inches on one side. The size of 4 inches represents a conservative upper bound of an RMI debris size that would still pass through gratings, trash racks, or radiological protection barriers by blowdown, containment sprays (CS), or post-accident pool flows (Reference [1]). A 2.0D ZOI is used for quantifying Transco® RMI debris and a 28.6D ZOI is used to quantify Mirror® RMI debris as no destruction testing is applicable to this insulation type. However, RMI debris has an insignificant head loss influence in fiber and particulate mixed debris beds, which are expected for Callaway, and was found to reduce head loss under certain circumstances (Reference [8]). The assumption is, the inclusion of RMI in the debris mixture for head-loss tests could potentially result in a non-conservative head loss because RMI may disrupt the formation of a contiguous fibrous debris bed (Reference [8]).

Response to 3.c.2. Provide bulk densities (i.e., including voids between the fibers/particles) and material densities (i.e., the density of the microscopic fibers/particles themselves) for fibrous and particulate debris:

Table 3.c-1 shows the debris material, bulk densities and material densities for fibrous debris other than latent debris. The values were obtained from NEI 04-07, Vol. 1 Guidance Report (GR) Table 3-2, which has been recognized by NEI 04-07, Vol. 2 SE, section 3.4.3.6 (Reference [1]), and are discussed further below.

Table 3.c-1: Fibrous Debris Characteristics

Debris Material	As-Fabricated Density (lb/ft^3)	Material Density (lb/ft^3)
NUKON®	2.4	159
Thermal-Wrap®	2.4	159

Table 3.c-2 shows the debris material, bulk density, material density and characteristic diameter for particulate debris (other than latent debris).

Characteristics associated with coatings particulate debris are discussed further in response to 3.h. Coatings Evaluation.

Table 3.c-2: RMI Debris Characteristics

Debris Material	As-Fabricated Density (lb/ft^3)	Material Density (lb/ft^3)	Characteristic Diameter (μm)
RMI	10	484	16.5

Response to 3.c.3. Provide assumed specific surface areas for fibrous and particulate debris:

Head loss across the installed recirculation strainers was determined via testing; thus, no surface area assumption was required. Therefore, these values are not provided as part of this response.

Response to 3.c.4. Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance:

The debris characteristics assumptions are consistent with NEI 04-07, Vol. 2 SE.

3.d. Latent Debris

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris existing within the containment and its potential impact on sump screen head loss.

1. *Provide the methodology used to estimate quantity and composition of latent debris.*
2. *Provide the basis for assumptions used in the evaluation.*
3. *Provide results of the latent debris evaluation, including amount of latent debris types and physical data for latent debris as requested for other debris under c. above.*
4. *Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris.*

The latent debris evaluation process described continues to conform to sections 3.5 and 4.2.2.2 of NEI 04-07, Vol. 2 SE (Reference [1]). The documented amount of latent debris in the containment building from the baseline survey was estimated to be less than 70 lb. The value of 200 lb of latent debris was used for additional conservatism.

Response to 3.d.1. Provide the methodology used to estimate quantity and composition of latent debris:

The latent debris methodology for computational failure analysis contribution to RoverD is consistent with sections 3.5 and 4.2.2.2 of NEI 04-07, Vol. 2 SE (Reference [1]): 200 lb of latent debris of which 85% was assumed to be particulate, the other 15% was assumed to be fiber. The fiber quantity used in the computational failure analysis for RoverD was 30 lb (12.5 ft^3), a bulk density of 2.4 lb/ft^3, a material density of 94 lb/ft^3, and a characteristic length of 5.5 μm.

Response to 3.d.2. Provide the basis for assumptions used in the evaluation:

Representative sampling methodology, latent debris mixture, and characteristics assumptions are consistent with sections 3.5.2.2 and 3.5.2.3 of NEI 04-07, Vol. 2 SE (Reference [1]).

Response to 3.d.3. Provide results of the latent debris evaluation, including amount of latent debris types and physical data for latent debris as requested for other debris under c. above:

<u>3.d.3a Results of Latent Debris Evaluation:</u>
The Containment Latent Debris Sampling Plan was implemented at Callaway for the first time during Refueling Outage XIV in October 2005. Its purpose was to obtain a baseline amount of latent debris existing in the containment building. The results

indicated that approximately 60 lb of latent debris was present in the containment building.

Since Refueling Outage XIV was a steam generator (SG) replacement outage, the latent debris sampling was repeated for Refueling Outage XV in March 2007. The results indicated that approximately 44 lb of latent debris was present in the containment building.

For analysis purposes, latent debris amount in containment was increased from the results observed in Refueling Outage XIV and XV to 200 lb in the analysis to provide additional margin for the containment latent debris assessment program. A distribution of 85% dirt/dust and 15% fibers is assumed, consistent with section 3.5.2.3 NEI 04-07, Vol. 2 SE (Reference [1]). The debris distribution used for this baseline analysis, therefore, was 170 lb dirt/dust and 30 lb latent fiber.

<u>3.d.3b Fibrous and Particulate Latent Debris Characteristics:</u>
Table 3.d-1 shows the bulk density, material density and characteristic diameter for fibrous latent debris. These values are consistent with section 3.5.2.3 of the NEI 04-07, Vol. 2 SE (Reference [1]).

Table 3.d-1: Fibrous Material Characteristics for Latent Debris

Debris Material	As-Fabricated Density (lb/ft^3)	Material Density (lb/ft^3)	Characteristic Diameter (μm)
Latent Fiber	2.4	94	5.5

Table 3.d-2 shows the solid density and characteristic diameter for particulate. These values are consistent with section 3.5.2.3 of the NEI 04-07, Vol. 2 SE (Reference [1]).

Table 3.d-2: Particulate Characteristics for Latent Debris

Debris Material	Microscopic Density (lb/ft^3)	Characteristic Diameter (μm)
Latent Particulate (dirt/dust)	169	17.3

Response to 3.d.4. Provide amount of sacrificial strainer surface area allotted to miscellaneous latent debris:

For 2016 testing, a sacrificial area reduction of 150 ft^2 was removed from the strainer. Applying an overlap of 25% results in 200 ft^2 of miscellaneous debris in containment.

3.e. 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.

1. *Describe the methodology used to analyze debris transport during the blowdown, washdown, pool-fill-up, and recirculation phases of an accident.*
2. *Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance.*
3. *Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results.*
4. *Provide a summary of, and supporting basis for, any credit taken for debris interceptors.*
5. *State whether fine debris was assumed to settle and provide basis for any settling credited.*
6. *Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers.*

This content is written to support the applicability of the computational analysis done to provide generated debris quantities at each weld location to the RoverD methodology.

Response to 3.e.1. Describe the methodology used to analyze debris transport during the blowdown, washdown, pool-fill-up, and recirculation phases of an accident:

The methodology employed for the debris transport calculation is primarily based on the analyses presented in NEI 04-07 Vol. 1 GR (Reference [1]), the corresponding NEI 04-07 Vol. 2 SE (Reference [1]), and the risk-informed pilot-plant. Complete details of the debris transport analysis are presented in Ref. [9]

Blowdown Phase Transport – Implemented the methodology of the risk-informed pilot-plant where:

- Fine debris used volume fractions to estimate the mass of fine debris in upper containment and lower containment. (Degraded qualified coatings, latent debris, or unqualified coatings were not analyzed for the blowdown phase.)
- Minimum credits from the Drywell Debris Transport Study (DDTS) were applied where appropriate for fiber retention on wetted surfaces in congested flow paths.
- Three volumes identified for break locations and expansion into upper containment, including the annulus, steam generator compartments, and the pressurizer compartment.

Washdown Phase Transport – Describes transport of debris carried by water flowing from higher containment elevations down to the pool; specifically by containment sprays initiated after a medium or large-break LOCA. The following assumptions apply to Washdown-Phase Transport:

- Upper containment spray is designed to be relatively uniform across the entire circular containment cross section, so spray interception by concrete and by equipment is assumed to occur in proportion to relative plan-view area.
- Cascading spill paths lead to 55% of spray flow entering the pool in the annulus, 25% of spray flow entering the pool through the refueling canal drains and the in-core tunnel, and 20% of spray flow entering the pool inside the secondary shield wall.
- Grating retention credits from the DDTS are applied consistent with guidance.

Pool Fill-Up Phase Transport – The transport of debris at the pool level due to break flow and CSS flow from the RWST. The areas below the containment floor elevation that fill up with the water/debris mixture and then remain stagnant for the remainder of the analyzed accident are referred to as inactive areas of the pool. Other areas of the pool are referred to as active areas. The following assumptions are applied to Pool Fill-Up Phase Transport:

- Small and large pieces of LDFG are not allowed to transport to inactive cavities during pool fill, leaving more debris available for transport during recirculation.
- No credit was taken for potential debris accumulation in the reactor cavity or in the in-core tunnel, leaving more debris available for transport in the pool.
- No debris transport to inactive cavities allowed until a pool height of 6 inches is reached, equivalent to the curb height circumscribing the emergency sumps.

Recirculation Phase Transport – Debris motion during active ECCS recirculation is based on Flow-3D simulations as described in response to 3.e.3 below using the following assumptions:

- Constant pool temperature held at peak of 271.74°F.
- Sprays injected at pool surface as mass sources with velocity determined by fall height.
- Settling velocity of fine particulates determined by Stokes' Law, which provides very little credit for settling in a turbulent pool.
- No consideration of RMI debris, because of minimal head loss effect compared to dominant fiber and particulate and because RMI can increase bed porosity and reduce head loss.

- No transport of intact fiber blankets because they cannot pass through gratings, can be captured on equipment and piping, sink when water saturated, and require very high pool velocities for transport.
- All fine fiber, coatings particulate, and latent debris in the pool at start of recirculation are assumed to be uniformly distributed.
- Transport fractions in pool determined for each debris type by identifying all computational cells that exceed the debris criteria for either tumbling velocity or TKE resuspension.

Response to 3.e.2. Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance:

Debris erosion of LDFG is the only area where debris transport analysis deviates from deterministic regulatory guidance. Methods implemented by the risk-informed pilot plant are applied. For debris in the containment pool 30-day erosion tests result in a 10% erosion fraction. For debris on gratings application of the DDT erosion tests result in a 1% erosion fraction.

Response to 3.e.3. Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results:

Flow-3D® Version 9.3 with the vendor's modified subroutine was the computational fluid dynamic (CFD) software used to compute recirculation transport fractions. The subroutine modification to the standard Flow-3D code was to enable the introduction of CS at the appropriate source locations, flow rates, and velocities. Transport of debris was determined based on local flow velocities and incipient tumbling velocities of debris types given in NEI 04-07. All fine debris (LDFG fines, all unqualified coatings, all qualified coatings, degraded qualified fines, and all latent debris) have a recirculation transport fraction of 100%. See response to 3.e.6 for transport results of other debris size distributions.

Response to 3.e.4. Provide a summary of, and supporting basis for, any credit taken for debris interceptors:

While Callaway does not have debris interceptors, debris barriers have been installed in all openings through the secondary shield wall near the emergency recirculation sumps. The barriers are made of perforated plate with 1/8th-inch-diameter holes. The capture of debris by the barriers is not considered because plant-specific test data is required for this credit.

Even though debris barriers were not credited for capture of debris, the CFD model accounts for presence of debris barriers. If debris barriers remain relatively clean during recirculation, these doorways will provide the most direct flow path for water inside the secondary shield wall to the strainers. However, if a debris bed forms on the barriers such that flow through the perforated plate is significantly impeded, more fluid will be diverted through the doorways on the North side of the secondary shield wall, which could substantially change flow field and turbulent kinetic energy (TKE) distributions, and by extension, the recirculation transport fractions. To address this uncertainty, undocumented sensitivity cases were conducted with the door barriers modeled as fully porous and as solid barriers that are impenetrable to fluid flow. An inspection of the results for the sensitivities showed greater transport fractions for solid barriers, so the barriers were assumed to be solid in all CFD simulations. To reiterate, debris barriers were assumed to be completely blocked, which resulted in the largest transport fractions, without the debris barriers reducing the inventory of debris available to transport. These assumptions are non-physical but result in the largest transport fractions.

Response to 3.e.5. State whether fine debris was assumed to settle and provide basis for any settling credited:

Fine LDFG, fine (or all) unqualified coatings, fine (or all) qualified coatings, fine degraded qualified coatings, and fine (or all) latent debris have a recirculation transport fraction of 100% and thus do not settle.

Response to 3.e.6. Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers.

For transported fiber debris amounts and a complete description of the RoverD methodology, see Attachment 3-3. The overall transport fractions were determined by incorporating results from all phases of transport for each break location and are presented in Table 3.e.1.

Table 3.e-1: Overall Transport Fractions

Debris Type	Debris Size	Debris Transport Fraction			
		Inside the Bioshield	Annulus	Upper Pressurizer Compartment	Lower Pressurizer Compartment
LDFG	Fines	99%	99%	99%	99%
	Small Pieces (<6”)	70%	60%	68%	64%
	Large Pieces (>6”)	66%	64%	0%	66%
	Fines Eroded from Smalls*	0%	1%	0%	0%
	Fines Eroded from Larges*	3%	4%	0%	3%
Unqualified Coatings	Fines	100%	100%	100%	100%
Qualified Coatings	Fines	99%	99%	99%	99%
Degraded Qualified Coatings	Fines	100%	100%	100%	100%
	Flat Small Chips (1/8”- 1/2”)	0%	6%	0%	0%
	Flat Large Chips (1/2”-2”)	0%	4%	0%	0%
	Curled Chips (1/2”-2”)	100%	96%	100%	100%
Latent Debris	Fines	96%	96%	96%	96%

*Fines eroded from small and large LDFG are transport fractions that are multiplied by the amount of the constituent generated to determine the mass that transports to the strainer. All debris that is eroded to a fine transports to the strainers at 100%.

The maximum transport fraction is applied to all break locations for RoverD analyses and is highlighted in Table 3.e.1. See Attachment 3-3 for more details.

3.f. 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.

1. *Provide a schematic diagram of the ECCS and CSS.*
2. *Provide the minimum submergence of the strainer under small-break loss-of-coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions.*
3. *Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions.*
4. *Provide a summary of the methodology, assumptions, and results of prototypical head loss testing for the strainer, including chemical effects. Provide bases for key assumptions.*
5. *Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen.*
6. *Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial thin bed formation.*
7. *Provide the basis for the strainer design maximum head loss.*
8. *Describe significant margins and conservatisms used in the head loss and vortexing calculations.*
9. *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation.*
10. *Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis.*
11. *State whether the sump is partially submerged or vented (i.e., lacks a complete water seal over its entire surface) for any accident scenarios and describe what failure criteria in addition to loss of net positive suction head (NPSH) margin were applied to address potential inability to pass the required flow through the strainer.*
12. *State whether near-field settling was credited for the head-loss testing and, if so, provide a description of the scaling analysis used to justify near-field credit.*
13. *State whether temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. If scaling was used, provide the basis for concluding that boreholes or other differential-pressure induced effects did not affect the morphology of the test debris bed.*
14. *State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure.*

The head loss and vortexing evaluations are revised due to 2016 test evaluation which replaces 2008 testing meant to support assumptions and corresponding conclusions contained in the earlier GL 2004-02 response. The computation failure analysis of

RoverD does not include head loss calculations. Instead a pass or fail criteria for break-specific head loss is implemented by comparing to the amount of fiber added in the 2016 test. See Attachment 3-3 for a complete description of the RoverD methodology.

Response to 3.f.1. Provide a schematic diagram of the emergency core cooling system (ECCS) and containment spray systems (CSS):

Schematic diagrams of the ECCS and the CSS are provided in Figures 3.f-1 and 3.f-2. The highlighted flow paths in Figure 3.f-1 depicted possible flow paths associated with containment recirculation sump ECCS operation, but do not depict specific operating conditions. For example, hot-leg and cold-leg recirculation are not aligned at the same time.

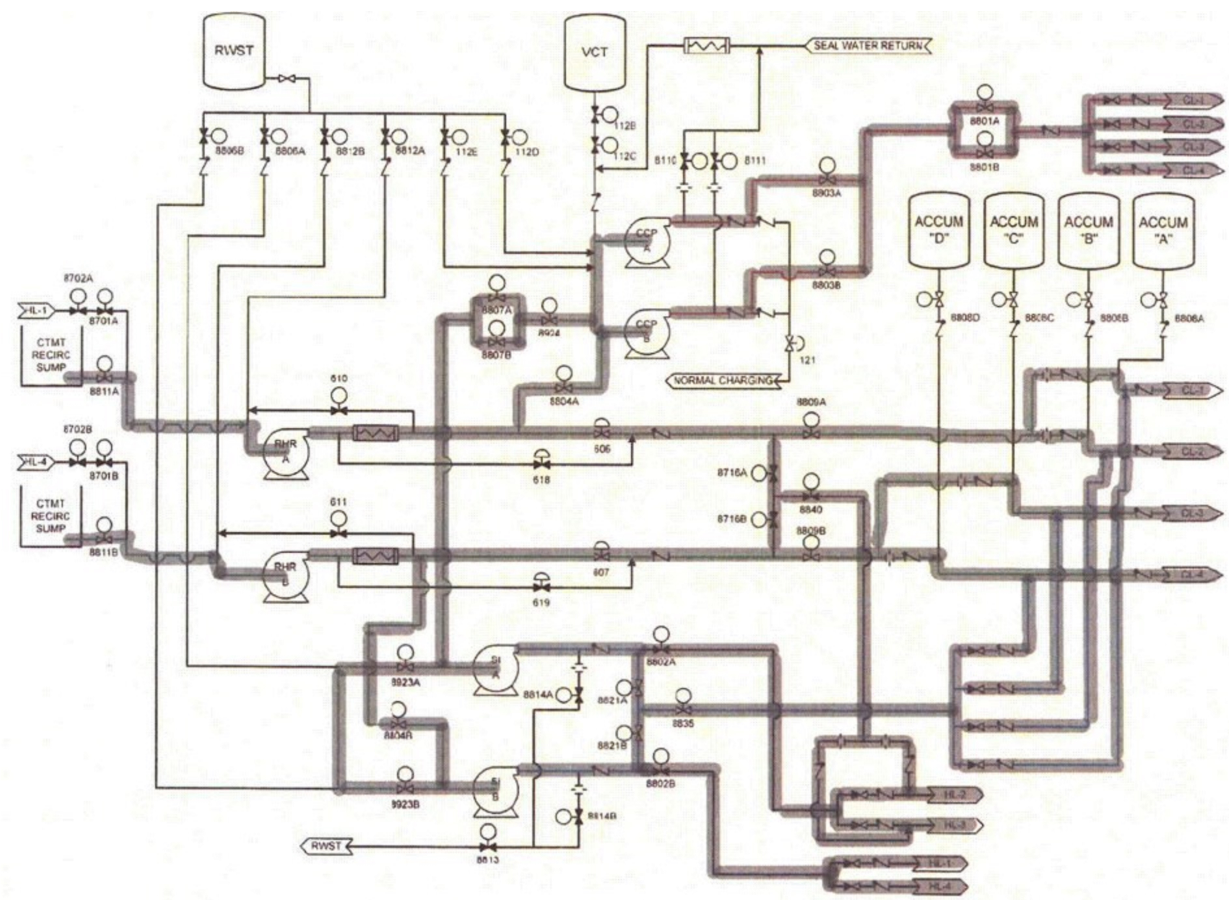


Figure 3.f-1: Callaway Unit 1 ECCS Process Flow Diagram

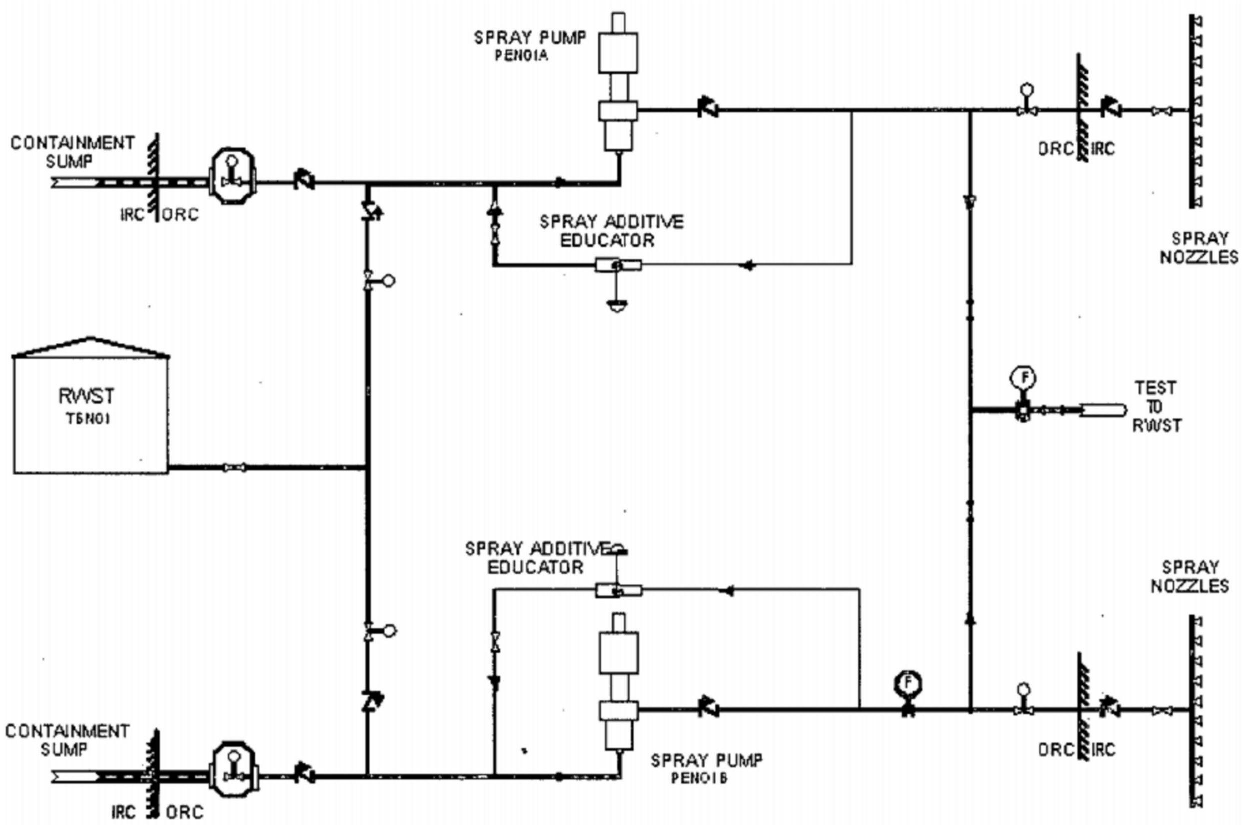


Figure 3.f-2: Callaway Unit 1 CSS Process Flow Diagram

Response to 3.f.2. Provide the minimum submergence of the strainer under small-break loss of coolant accident (SBLOCA) and large-break loss-of-coolant accident (LBLOCA) conditions:

For the large-break LOCA condition, the containment recirculation sump strainers are submerged with greater than 8 inches of water above the top of the strainers at the time of ECCS switchover to recirculation. For the small-break LOCA condition, the recirculation sump strainers are submerged with approximately 2 inches of water above the top of the strainers at the time of ECCS switchover to recirculation. Note that the minimum submergence occurs at ECCS switchover to recirculation.

Response to 3.f.3. Provide a summary of the methodology, assumptions and results of the vortexing evaluation. Provide bases for key assumptions:

At the conclusion of the full debris load (FDL) and thin bed (TB) head-loss tests, the water level was lowered to the minimum large-break LOCA condition of 8 inches to observe low submergence conditions. During the FDL head-loss test, vortexing was not observed. During the TB head-loss test, surface swirl and small dimples were observed, but an air core did not form. Therefore, for a LBLOCA, air ingestion due to vortex formation is unlikely to occur.

Small-break LOCA conditions were not tested. The tested large-break LOCA conditions have a flow rate and submergence 6 times larger and 4 times larger, respectively, than small-break LOCA conditions. A comparative analysis of the change in Froude number between large-break and small-break LOCA conditions yields insights to whether a vortex is more or less likely to form than the tested large-break LOCA condition, and results in a Froude number reduction for small-break LOCA conditions. Theoretically, small-break LOCA conditions are less likely to form a vortex than the tested large-break LOCA conditions. Therefore, vortexing in a manner capable of entraining air are concluded to not occur for small-break LOCA.

Response to 3.f.4. Provide a summary of the methodology, assumptions, and results of prototypical head loss testing for the strainer, including chemical effects. Provide bases for key assumptions:

Summary

Callaway contracted Alden Research Laboratory (Alden) to perform testing to assess head loss development across ECCS sump strainers, identical to those installed at Callaway, after a LOCA and identify the resulting limits on debris quantities that can be tolerated without exceeding the provided head loss acceptance criteria.

The head loss test sequence included two large scale tests – a FDL test and a TB test in support of Callaway closure of GL 2004-02. The FDL test was executed the week of June 20th of 2016. The TB test was executed the week of June 27th of 2016 with the NRC witnessing testing.

The FDL test introduced incremental quantities of conventional debris (fibrous debris mixed with corresponding particulates). The debris types were distributed evenly among all batches. The TB test examined whether the quantity of particulates in the FDL test would yield acceptable head loss results under conditions where the quantity of particulates builds a debris bed with relatively small quantity of fiber. For both tests, chemical debris was added to the test tank after all of the conventional debris was added. Prior to adding chemical debris, the debris bed was characterized by allowing head loss stabilization, and performing flow and temperature sweeps.

The test facility featured two prototypically sized and flow-controlled strainer stacks arranged one behind the other with respect to the direction of the approach flow as presented in Figure 3.f-3. The head loss test strainer was situated in the pit arrangement similar to the plant, without the 6-inch curb, and featured prototypical gaps between adjacent strainer discs. The test facility was configured to promote complete and uniform debris transport to the test strainer. The head loss testing was performed with a clearance between the wall and the strainers similar to the distance between strainers instead of half that distance, which would represent the prototypical symmetry line between the strainer stacks. Nevertheless, the test environment did not permit excessive settling and allowed the strainer disks to be loaded with debris in a relatively uniform manner.

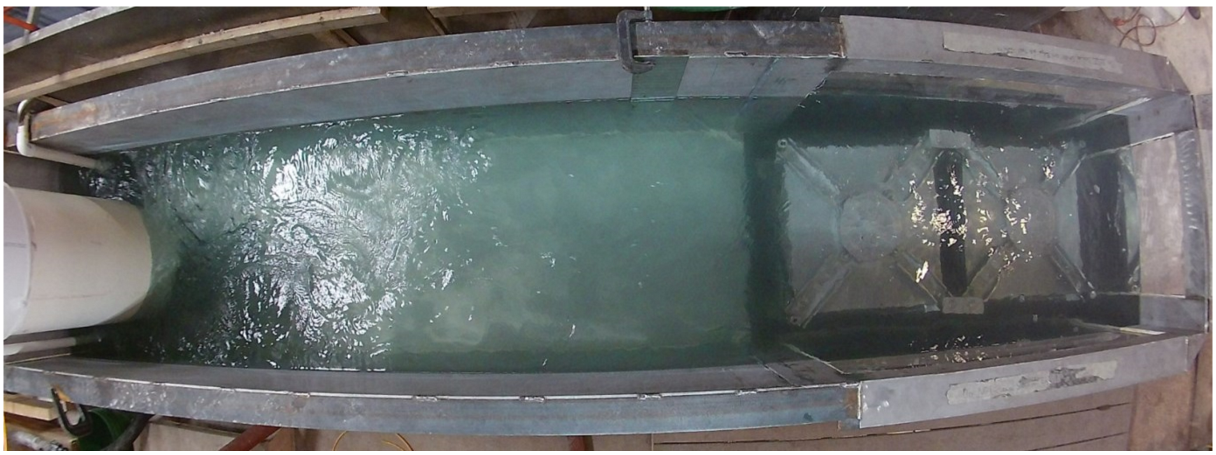


Figure 3.f-3: Picture of the Callaway Strainer Test Tank

Both tests conducted did not exceed the allowable head loss margin as defined for the FDL and TB test.

<u>Model Description</u>
For head loss testing, two plant vertical strainer stacks were used. Two strainer stacks represent approximately 11% (0.1103 scale factor [10]) of the installed strainer area of one Callaway strainer train after a sacrificial area reduction of 150 ft^2 to account for miscellaneous debris. Strainer stacks were installed in a manner that maintains the flow-controlled nature of the plant strainer configuration. Each vertical stack contained one, 7-disk module on the bottom with three, 11-disk modules situated atop. The two vertical stacks were positioned one behind another with respect to the approach flow in a pit. The pit was configured to model the plant geometry. For the tests executed, bridging to the wall did not occur since the debris bed formed predominately between the disks and the debris layer that accumulated external to the strainer stacks did not reach 2 inches beyond the stacks. The increased gap did not cause significant settling in the perimeter around the strainer and the flow patterns generated allowed the strainer stack to load relatively evenly. Furthermore, the 6-inch curb that surrounds the sumps in the plant was not modelled in the test to ensure that all of the added debris had an opportunity to be transported to the strainer.

To achieve the desired transport of debris in the test tank, a single 16-inch diameter mixing nozzle was implemented. The mixing nozzle supplied sufficient turbulence to suspend fibrous and particulate debris without disrupting debris bed development. The main components of the test included the test tank, debris introduction hopper, and the transition tank. Debris was added to the hopper and mixed by turbulent flow within the hopper. The mixed debris was gravity drained from the hopper to the test tank. The loop was also equipped with a transition tank that effectively increased the volume of the test tank. The total flow through the test strainer, the flow to the debris introduction hopper, and the flow to the transition tank were measured by three flow meters.

The approach velocity target was conservatively increased by 15%, constant throughout the test, and was only altered for flow sweeps. The approach velocity of 0.007 ft/sec translated to a target test operating flow rate of 1094 gpm with a 2% tolerance.

<u>Debris Surrogates and Preparation</u>
NUKON® fines were the surrogate for all LDFG sizes. Preparation began by cutting the single-sided baked NUKON® blanket into pieces at a nominal 2” x 2” size. The tough outer layer of the un-burnt portion of the NUKON® blanket (less than 1/8” thick) was separated from 2” x 2” debris pieces and torn into smaller pieces to help it break up consistently.

Prepared debris was initially wetted with heated test water until the base material was saturated and the high pressure spray nozzle was submerged. Preparation was considered acceptable once their composition was predominantly Class 2, consisting mainly of individual fibers with lesser quantities of fiber shards and small entanglements (Reference [10]).

PCI PWR Dirt and Dust Mixture Preparation - the procured PCI PWR Dirt and Dust did not require additional processing. PCI PWR Dirt and Dust was weighted and sprinkled into the test tank immediately upstream of the strainer configuration. The direct introduction into the test tank was used to prevent the PCI PWR Dirt and Dust from forming large agglomerations with fiber, which ultimately could have caused the debris introduction hopper to clog.

Silica Particulates were used as surrogates for all qualified coatings, unqualified coatings, and degraded qualified coatings. Degraded qualified coatings that fail as chips were conservatively represented in the test as particulates. Particulates typically induce a greater head loss than chips. Also, unlike chips, particulates will not disrupt a contiguous debris bed that likely decreases the head loss. Also, a volume scale was applied for particulates to conserve the quantity of particulates.

Min-U-Sil 5, Sil-Co-Sil 53, and Agsco 70 are the silica particulates implemented to create the desired size distribution. The size distribution was similar to the risk-informed pilot plant size distribution used in their RoverD head loss test; see Figure 3.f-4. All the silicates had the same material density of 164.6 lbm/ft^3.

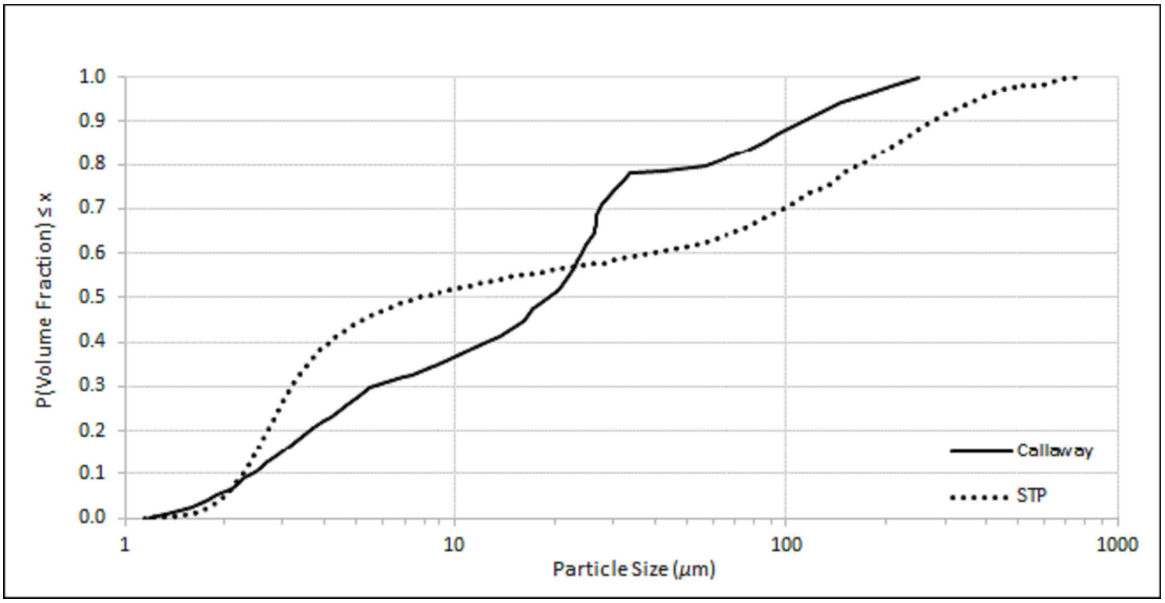


Figure 3.f-4: Coatings Debris Surrogate Particulate Size Distribution

Chemical Debris Preparation - calcium phosphate and aluminum oxyhydroxide (AlOOH) were the chemical precipitates prescribed for the test. The chemical debris was generated under preparation outlined in WCAP-16530-NP-A. To generate chemical precipitate, deionized water was poured into a mixing tank to a verified graduation marking. The measured water volume was mixed continuously prior to any chemical addition and mixing continued until after the chemical debris in the mixing tank was added to the test. Next, the chemical salt was added to the mixing tank and the pH of the solution was monitored until it was stable for 15 minutes. Then, the base was added. After the pH of the solution was stable for 15 minutes, the final pH value was recorded and a settling test was executed. All precipitates met the acceptance criteria provided in WCAP-16530-NP [11].

Full Debris Load Test

Debris amounts that were scaled for the FDL test are given in the Table 3.f-1. These values represent the debris amount that transports to the strainer for single-train operation.

Table 3.f-1: Debris Amounts for 2016 Full Debris Load (LBLOCA) Test

Debris Component	Plant Qty	Test Quantity[1]	Test Surrogate
Particulate[2]	1490 lbm	164.40 lbm	Min-U-Sil 5
	2140 lbm	236.02 lbm	Agsco 70
	2140 lbm	235.99 lbm	Sil-Co-Sil 53
Latent Particulate	30 lbm	3.28 lbm	PCI PWR Dirt & Dust
Fiber	300 lbm	33.09 lbm	NUKON® Fines
Chemical Precipitate	25 kg	2.76 kg	Calcium Phosphate
Chemical Precipitate	215 kg	23.7 kg	Sodium Aluminum Silicate

[1] Scale factor for testing is 0.1103
[2] Volume scale applied

Note that the latent particulate plant quantity used in the FDL test, 30 lbm, bounds plant inventory estimates, but is less than the generic prescribed load of 170 lbm that was tested in the thin bed test, with similar resulting head loss, and used for all other analyses.

Conventional debris was introduced following an incremental batching schedule. The batching schedule allowed for the determination of head loss across the strainer at incremental debris quantities. Only NUKON® fines were used as a surrogate for fibrous debris. Implementing the test using only NUKON® fines will tend to produce a result with a higher head loss than a test with some of the NUKON® mass introduced as smalls. The addition of conventional debris (fibrous debris and particulates) did not exceed the allowable conventional debris head loss limit.

Following the completion of conventional debris additions, flow sweeps and temperature sweeps were executed and chemical debris introduced consisted of calcium phosphate and aluminum oxyhydroxide. One calcium phosphate batch and five ALOOH batches were introduced to match the predicted plant quantity.

After all of the chemical debris was introduced the debris bed was characterized. Head loss was first stabilized at 120°F. Then a flow sweep was conducted. Following the flow sweep, the temperature was reduced below 100°F. The head loss was stabilized again, and a final flow sweep was conducted. Following temperature and flow sweeps, the final pH and conductivity of the test water were recorded and the test loop was drained.

The maximum debris bed head loss for the FDL test is 1.45 psid at 120 °F and with a flow rate of 1102 gpm.

Thin Bed Test

The debris amounts that were scaled for the 2016 TB test are given in the Table 3.f-2. These values represent the debris amount that arrives at the strainer for one-train operation.

Table 3.f-2: Debris Amounts for 2016 Thin Bed Test

Debris Component	Plant Quantity	Test Quantity	Test Surrogate
Particulate	1490 lbm	164.37 lbm	Min-U-Sil 5
Particulate	2140 lbm	236.18 lbm	Agsco 70
Particulate	2140 lbm	236.18 lbm	Sil-Co-Sil 53
Latent Particulate	170 lbm	18.72 lbm	PCI PWR Dirt & Dust
Fiber	150 lbm	17.43 lbm	NUKON®
Chemical Precipitate	25 kg	2.75 kg	Calcium Phosphate
Chemical Precipitate	215 kg	23.68 kg	Sodium Aluminum Silicate

First, all of the particulate debris was introduced in one continuous fashion via the hopper. PCI PWR Dirt and Dust was added separately near the end of the particulate debris introduction directly to the test tank near the ledge of the strainer pit. After all of the particulate debris was added to the test tank, batches of NUKON® fines were added to the test tank via the hopper. Fiber batches were introduced to the test with masses equivalent to 1/16-inch of coverage on the test strainer.

A total of four NUKON® fines batches were introduced to the test tank. The second and third addition of fiber both had a similar head loss increase, so a fourth batch was introduced to get to the point where the head loss increase for the last fiber addition was distinctly lower than previous additions.

The debris bed flow and temperature parameters were varied after the completion of conventional debris additions. Temperature was maintained at 120°F and the head loss was stabilized. After the head loss was stabilized a temperature sweep and flow sweep were conducted.

A total of one calcium phosphate addition and six additions of ALOOH were introduced. The total quantities were the same as in the FDL test. After the completion of the chemical debris introductions, temperature and flow sweeps were performed on the debris bed. The final pH and conductivity of the test tank was then taken, the pump was stopped and the loop was slowly drained.

The maximum debris bed head loss for the TB test is 0.9 psid at 100 °F and with a flow rate of 1102 gpm.

<u>Clean Strainer Head Loss</u>
Clean strainer head loss (CSHL) measurements were recorded at low and high temperatures and various flow rates at the beginning of each test. The CSHL data was taken before any debris was added to the tank. The data was taken for each flow rate after the flow had been allowed to stabilize. The data was processed to develop an average loss coefficient for the clean strainer that was applied to all tests to determine the debris laden head loss.

<u>Single Train Operation</u>
Single train operation was used for scaling debris loads to the test.

<u>Results:</u>
Two head loss tests were performed in support of Callaway's closure of GSI-191. Neither test exceeded the allowable head loss margin defined for the FDL test and TB test. The FDL test demonstrated that the conventional debris load was acceptably accommodated by the Callaway sump strainer configuration under the test conditions defined. The TB test showed that a particulate-dense debris bed did not exceed the head loss measured during the FDL condition or the head loss limit.

The objective of the TB test was to verify that FDL conditions are indeed limiting for strainer performance. The TB test built a filtering debris bed with the lowest possible amount of fiber to promote the formation of a particulate saturated debris bed. Since the particulate debris quantity for the executed test sequence was very high, saturation was likely to have already occurred during the FDL test. The conducted TB test confirmed that the FDL conditions are limiting.

Response to 3.f.5. Address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen:

Head loss tests of the strainers showed that the strainers have acceptable performance for the design basis particulate amounts, RoverD fiber threshold mass, and design basis chemical quantity that were added to the test tank. The test tank was designed to transport all debris to the strainer, so a very small amount of debris settled and was not accommodated by the strainer. Figure 3.f.5 and Figure 3.f.6 display the upstream, debris laden strainer stacks for the FDL and TB tests, respectively. The TB and FDL test are complementary and demonstrate the robustness of the strainer.

Figure 3.f-5: Post FDL Test, Front Side of Upstream Strainer Stack, Top (Left) and Bottom (Right)

Figure 3.f-6: Post TB Test Upstream Strainer Stack

Response to 3.f.6. Address the ability of the screen to resist the formation of a "thin bed" or to accommodate partial thin bed formation:

A thin debris bed with low porosity that challenges the acceptable head loss did not form. The strainer head loss was acceptable for the TB test, and head loss was less than the FDL test.

Response to 3.f.7. Provide the basis for the strainer design maximum head loss:

The basis for the strainer design maximum head loss considers the strainer performance metrics of net positive suction head margin, deaeration, potential for flashing, and structural limits.

Also, in the RoverD methodology the maximum debris loads from a successful head-loss test are implemented as deterministic acceptance criteria for strainer loading during risk-informed simulations. A deterministic fiber threshold of 300 lbm that was tested with bounding particulate loads is the strainer loading acceptance criteria. See Attachment 3-3 for a complete description of the RoverD methodology.

Response to 3.f.8. Describe significant margins and conservatisms used in the head loss and vortexing calculations:

Head loss is based on laboratory testing rather than a calculation. Numerous conservatisms were implemented during testing as outlined in the following list.

- LDFG fines were used as a surrogate for LDFG smalls and larges.
- The approach velocity was conservatively increased by 15% (beyond the approach velocity increase due to miscellaneous debris).
- The scaling factor applied was for single train operation.
- Test procedures were designed to promote uniform debris distribution on the strainer to maximize head loss.
- The test tank did not have the 6-inch curb around the strainers to maximize debris transport.
- Debris material that demonstrated reductions in strainer head loss, such as reflective metallic insulation (Reference [8]), was excluded from the test.

Evaluation of the potential for vortexing was predominantly based on laboratory testing rather than a calculation. At the conclusion of head-loss tests, vortexing tests were conducted at the maximum large-break LOCA flow rate and minimum large-break LOCA submergence. For small-break LOCA, a comparative analysis was performed using the Froude equation to conclude vortices with a solid air core would not form. See the response for 3.f.3 for more details.

Additional discussions of margin for Callaway 2016 head loss testing are available in the Defense-in-Depth and Safety Margin discussions of Attachment 3-4.

Response to 3.f.9. Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the clean strainer head loss calculation:

The calculation (Reference [12]) utilized two distinct methodologies based on the entire strainer assembly configuration in determining the CSHL: (1) strainer and (2) structural support plenum and discharge. The first methodology for strainer only head loss employed an equation that was experimentally derived and which was used to determine the strainer head loss contribution. The second methodology utilized classical standard hydraulic head loss coefficients for the plenum and discharge to the sump. The individual head loss results from the strainer and plenum were added together to obtain the head loss for the entire strainer assembly configuration.

The strainer surface areas utilized in the calculation are based on initially calculated values using a minimum surface area of 3279.5 ft^2. The actual strainer area was increased, due to design enhancements and structural revisions, to 3311.5 ft^2, which is an increase of less than 1%.

A flow rate of 8830 gpm is used to determine the CSHL, while the maximum flow rate is 8750 gpm.

The CSHL is increased by 6% to account for measurement uncertainty during testing.

The results of CSHL including uncertainty are presented in Table 3.f-3.

Table 3.f-3: Temperature Dependent CSHL

Clean Strainer Head Loss at 140°F, ft	Clean Strainer Head Loss at 212°F, ft
0.7	0.6

Response to 3.f.10. Provide a summary of the methodology, assumptions, bases for the assumptions, and results for the debris head loss analysis:

The total strainer head loss consists of a CSHL in addition to a debris laden head loss that includes chemical precipitates. As discussed in response to Issue 3.f.9, the

CSHL is determined from an experimentally derived equation and classical, standard hydraulic head loss coefficients. The debris laden head loss is based on laboratory testing of the strainer module (Reference [10]).

Debris laden head loss is determined during testing that occurred at 120 °F and at a flow rate 15% greater than large-break LOCA conditions. For all large-break LOCA strainer performance metrics, the debris laden head loss was not scaled for temperature or flow rate, which would reduce the head loss. The maximum debris laden head loss from testing is 1.5 psi at 120 °F (or 3.5 ft at 120 °F). Table 3.f-3 displays the CSHL. Table 3.f-4 displays the total strainer head loss.

Table 3.f-4: Temperature Dependent Total Strainer Head Loss

Total Head Loss at 140°F, ft	Total Head Loss at 212°F, ft
4.2	4.1

Response to 3.f.11. State whether the sump is partially submerged or vented (i.e., lacks a complete water seal over its entire surface) for any accident scenarios and describe what failure criteria in addition to loss of net positive suction head (NPSH) margin were applied to address potential inability to pass the required flow through the strainer:

The sumps are fully submerged for SBLOCA and LBLOCA conditions. The sumps are not vented.

Response to 3.f.12. State whether near-field settling was credited for the head-loss testing and, if so, provide a description of the scaling analysis used to justify near-field credit:

Strainer head loss testing did not credit near-field settling. The test tank was designed to maximize transport to the strainers. With the exception of latent particulate which was poured in just upstream of the strainers, only fine debris was used. Also, adverse agglomeration of debris did not occur.

Response to 3.f.13. State whether temperature/viscosity was used to scale the results of the head loss tests to actual plant conditions. If scaling was used, provide the basis for concluding that boreholes or other differential-pressure induced effects did not affect the morphology of the test debris bed:

Temperature/viscosity was not used to scale the results of the head loss test to actual plant conditions. Therefore, head losses at the test temperature of 120 °F are assumed to represent head losses at higher plant temperatures.

Response to 3.f.14. State whether containment accident pressure was credited in evaluating whether flashing would occur across the strainer surface, and if so, summarize the methodology used to determine the available containment pressure:

Containment accident pressure was credited in evaluating potential for flashing across the strainer surface. A containment accident pressure of 1.7 psi is credited for temperatures 212 °F and above which equates to approximately 10% of the available accident pressure. RG 1.82 states, "The calculation of available containment pressure and sump/pool water temperature as a function of time should underestimate the expected containment pressures and overestimate the sump/pool water temperatures." Since containment pressure and sump/pool water temperature are dependent, the stated requirements are achieved by post-processing a design basis containment response analysis (Reference [13]) where containment pressure is reduced by the saturation pressure and 1.8 psig. Saturation pressure is required to maintain the fluid as a liquid and thus is not available containment pressure. The reduction of 1.8 psig is determined by reducing the initial containment pressure of the design basis analysis from a technical specification maximum of 1.5 psig (Reference [13, 14]) to the technical specification minimum of -0.3 psig (Reference [14]). These conditions result in the maximum sump/pool water temperatures and minimum containment pressure.

3.g. Net Positive Suction Head (NPSH)

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

1. *Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level.*
2. *Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions.*
3. *Provide the basis for the required NPSH values, e.g., three percent head drop or other criterion.*
4. *Describe how friction and other flow losses are accounted for.*
5. *Describe the system response scenarios for LBLOCA and SBLOCA's.*
6. *Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation.*
7. *Describe the single failure assumptions relevant to pump operation and sump performance.*
8. *Describe how the containment sump water level is determined.*
9. *Provide assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin.*
10. *Describe whether and how the following volumes have been accounted for in pool level calculations: empty spray pipe, water droplets, condensation and holdup on horizontal and vertical surfaces. If any are not accounted for, explain why.*
11. *Provide assumptions (and their bases) as to what equipment will displace water resulting in higher pool level.*
12. *Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source.*
13. *If credit is taken for containment accident pressure in determining available. NPSH, provide description of the calculation of containment accident pressure used in determining the available NPSH.*
14. *Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature.*
15. *Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature.*
16. *Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode.*

The information in this section revises information previously provided by Ameren Missouri to GL 2004-02, section 3.g. (Reference [2]). The NPSH calculation is revised due to 2016 test evaluation which replaces 2008 testing meant to support assumptions and corresponding conclusions contained in the earlier GL 2004-02 response. The

NPSH margin evaluation process described below conforms to sections 3.7 and 4.2.5 of NEI 04-07, Vol. 2 SE (Reference [1]).

Response to 3.g.1. Provide applicable pump flow rates, the total recirculation sump flow rate, sump temperature(s), and minimum containment water level:

RHR Pump flow rate during recirculation is 4800 gpm for each pump. CS pump flow rate during recirculation is 3950 gpm for each pump. The total strainer flow rate is 8750 gpm for each strainer.

The maximum and minimum large-break LOCA pool temperature is approximately 265 °F and 140 °F. NPSH analysis is evaluated at 212 °F.

Large-break LOCA minimum water level is elevation 2001' 10" and occurs at ECCS switchover. Small-break LOCA minimum water level elevation is 2001' 3.5".

Response to 3.g.2. Describe the assumptions used in the calculations for the above parameters and the sources/bases of the assumptions:

The flow rates implemented in the NPSH analysis are maximums derived from pre-operational tests.

NPSH analysis is determined at 212 °F because this temperature provides the limiting NPSH margin. Below 212 °F atmospheric pressure (or subcooling of the fluid) is in direct competition with increasing system head losses which are a function of fluid properties. Subcooling margin increases with decreasing temperature at a rate greater than the increasing system head losses. Therefore, NPSH margin is gained as temperature decrease below 212 °F. At temperatures greater than 212 °F, containment pressure is equal to vapor pressure because containment accident pressure is not credited for NPSH analysis. Therefore, NPSH available is only a function of static head and head loss. For this analysis static head is constant and is selected based on a minimum large-break LOCA. Head loss increases as temperature decreases. Therefore, the minimum temperature within the temperature range, 212 °F, is analyzed. To recap, 212 °F is the lowest temperature which produces the highest head loss when subcooling does not provide an additional net head. Also, a CSHL of 0.7 ft at 140 °F and debris bed head loss of 3.5 ft at 120 °F were conservatively applied to the NPSH calculation at 212 °F without a correction for temperature, which would reduce the head losses.

For large-break LOCA NPSH analysis, the minimum large-break LOCA water level occurs at ECCS switchover and was applied in the NPSH margin evaluation.

Response to 3.g.3. Provide the basis for the required NPSH values, e.g., three percent head drop or other criterion:

NPSH required was determined by the pump vendors and applied in NPSH margin analyses as specified. NPSH required was not corrected for temperature. NPSH required was increased for air in the fluid at the pump suction inlet per RG 1.82.

Response to 3.g.4. Describe how friction and other flow losses are accounted for:

The friction and flow loss values are based on standard industry accepted estimates of piping friction and fitting head losses at maximum flow rates. Equations used to determine head losses are displayed below.

$$H_L = f\frac{L}{D}\frac{v^2}{2g} \quad or \quad H_L = f\left(\frac{L}{D}\right)_{equiv}\frac{v^2}{2g} \quad or \quad H_L = K\frac{v^2}{2g}$$

where

H_L is the head loss attributed to friction, ft
f is the friction factor, unitless
L is the pipe length, ft
D is the inside pipe diameter, ft
$(L/D)_{equiv}$ is the fitting head loss coefficient
K is the fitting's head loss coefficient
v is the fluid velocity, ft/s
g is the acceleration caused by gravity, ft/s^2

Friction factors are determined with a Moody chart or an empirical derivation of a Moody chart.

Response to 3.g.5. Describe the system response scenarios for LBLOCA and SBLOCA's:

For LOCAs, there are two modes of operation: the injection mode and the recirculation mode of operation.

<u>Large-Break LOCA</u>
During a large-break LOCA, depressurization of the RCS results in a pressure decrease in the pressurizer. The reactor trip signal subsequently occurs when the pressurizer low pressure trip setpoint is reached. Once RCS pressure is less than approximately 600 psig, the four accumulator tanks will inject into the RCS. A safety injection signal (SIS) is generated when the low pressurizer pressure SI setpoint is reached. A containment spray actuation signal (CSAS) is generated when the

containment pressure setpoint is reached. Upon receipt of an SIS and CSAS, the ECCS and CSS are activated, commencing the injection mode of ECCS and CSS operation. This mode of operation consists of both trains of the ECCS pumps running (two charging pumps, two SI pumps, and two RHR pumps) and both CS pumps taking suction from the RWST and delivering water to the RCS.

Continued operation of the RHR pumps supplies water during long-term cooling. After the water level of the RWST reaches a minimum allowable value, coolant for long-term cooling of the core is obtained by automatically switching to the cold-leg recirculation mode of operation in which borated water is drawn from the containment recirculation sumps and returned to the RCS cold legs (CLs) by the RHR pumps. The CS pumps, SI pumps, and CCP pumps are manually aligned to the containment recirculation sumps with a timed operator action and continue to operate in recirculation mode.

Approximately 13 hours after initiation of the LOCA, the SI pumps are realigned to supply water to the RCS hot legs to mitigate the boric acid concentration in the reactor vessel, while RHR pumps and CCP pumps continue to inject into CLs.

<u>Small-Break LOCA</u>
For a small-break LOCA, information provided by Westinghouse indicates that for "a typical Westinghouse 4-loop PWR with a larger dry containment, such as Wolf Creek or Callaway, an equivalent 3-inch diameter break or smaller may result in the RCS pressure equilibrating at 1000 psi to about 1200 psi. At this pressure, the SI accumulators will not discharge. For breaks of greater than about an equivalent 3-inch diameter, the plant would undergo a sufficiently rapid depressurization that the SI accumulators would discharge".

During a small-break LOCA scenario, a SIS will start both trains of charging, SI and RHR pumps in the injection mode from the RWST to the RCS (cold-leg injection). The charging pumps will inject water immediately. If RCS pressure continues to decrease below the shut-off head of the SI pumps (~1550 psig), they will also start injecting into the RCS. As the control room operators progress through their emergency procedures, they may shut-off the RHR pumps based on RCS pressure (stable or increasing). The SI accumulators are also aligned to inject into the RCS when the RCS pressure drops below the accumulator pressure. The RHR pumps will not start injecting until RCS pressure drops below the shutoff head of the RHR pumps (~ 325 psig). If the combination of the charging pumps and SI pumps does not equal the break flow, RCS pressure will continue to decrease. If RCS pressure stabilizes somewhere above the shut-off head of the RHR pumps, they may be turned off. For a small-break LOCA pressure in the containment building is not expected to exceed the pressure required for CSAS. Therefore, CS is not expected to actuate during a small-break LOCA.

The objective of the control room operators is to cool down and depressurize the RCS so that the RHR pumps may be aligned from the RCS hot legs and recirculated back to the cold legs. But, if the RWST injects enough fluid to where two of the four normal sump level indicators read greater than 6' 1", the RHR pumps will be aligned to take suction from the containment emergency recirculation sumps and supply suction to the SI and charging pumps. If RCS pressure is below the shut off head of the RHR pumps, the RHR pumps will also inject into the RCS. The recirculating water will be cooled as it is pumped through the RHR heat exchangers.

Response to 3.g.6. Describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation:

For a large-break LOCA, prior to the recirculation phase of the analyzed postulated accident, both safety trains of ECCS pumps are running, which includes two charging pumps, two SI pumps, and two RHR pumps. In addition, both CS pumps are running. Following initiation of the recirculation phase, the status remains as described above.

Response to 3.g.7. Describe the single failure assumptions relevant to pump operation and sump performance:

For GSI-191 the single worst failure is loss of a strainer because all of the debris is loaded on a single strainer, which induces failures at smaller break sizes. RoverD implemented the loss of a train for all analysis.

Response to 3.g.8. Describe how the containment sump water level is determined:

Given the net mass of water added to the containment floor, determined by the difference between water sources and holdup volumes, the post-LOCA containment building water level is calculated by an accumulation rate correlation that is a function of elevation.

Sources that add water to containment include:
1. RWST,
2. RCS,
3. Accumulators,
4. Initial atmosphere water vapor.

Features that remove water from the containment sump include:
1. Water vapor in the containment atmosphere,
2. Water volume remaining in the RCS,
3. Water film on surfaces,

4. Water volume in ECCS and CS piping,
5. HVAC duct and piping,
6. Water in transit from the CS nozzles and the break to the containment sump,
7. Water in the refueling pool and other holdup,
8. Water below the 2000 ft elevation,
9. Water in other miscellaneous holdup such as trenches, pits, etc.

Response to 3.g.9. Provide assumptions that are included in the analysis to ensure a minimum (conservative) water level is used in determining NPSH margin:

The RWST, RCS and the SI accumulator inventories were assumed to be the same density as pure water. This assumption is reasonable since the boric acid concentrations are small (i.e. less than or equal to 2500 ppm).

The total RHR and CS piping hold-up volume calculated was increased by a conservative 5% to account for additional volume that was not considered (such as higher cross-sectional area for valves, other fittings, and drain lines).

An assumption of 5% SG tube plugging is assumed in the water level calculation. Following installation of replacement SGs in October 2005, a combined total of one tube in the four SGs was plugged; therefore the use of 5% plugging is a conservative assumption.

The temperature of the water within the SI accumulators is assumed to be equal to the maximum initial containment air temperature consistent with the accident analysis of 120 °F. This approach is conservative because the density of water decreases with increasing temperature, limiting the mass of water that could spill into containment.

The water density at the sump temperature is used to calculate the post-LOCA RCS volume since it would be difficult to accurately quantify the average RCS water inventory temperature following the break. This is conservative because the RCS temperature will be higher than the sump temperature due to decay heat and residual RCS piping and component heat.

To account for miscellaneous holdup volumes not specifically quantified, a miscellaneous holdup quantity of 250 ft^3 is included.

The initial RCS volume is minimized by assuming a minimum pressurizer volume of 38%. This assumption is based on the nominal pressurizer span at 100% power and Tavg = 570.7 °F.

Also, the minimum volume for the water sources was applied with the maximum volume of the water holdup.

Response to 3.g.10. Describe whether and how the following volumes have been accounted for in pool level calculations: empty spray pipe, water droplets, condensation and holdup on horizontal and vertical surfaces. If any are not accounted for, explain why:

All volume questioned were accounted for in the pool level calculation as holdup volumes. Further description is provided below.

1. Empty spray pipe: Water volume required to fill initially empty CS pipes (and RHR pipes) is 578 ft^3 and is removed from the active volume that contributes to pool height.
2. Water droplets: Water droplets are held up in the air as steam and have a volume of 4126 ft^3. Water droplets are removed from the active volume that contributes to pool height.
3. Holdup on horizontal and vertical surfaces: A film thickness of 1/32" is assumed to form on wetted surfaces and has a volume of 1164 ft^3. This volume is removed from the active volume that contributes to pool height.

Also, to account for uncertainties, an additional miscellaneous holdup of 250 ft^3 is removed from the active volume that contributes to pool height as stated in the Response to 3.g.9.

Response to 3.g.11. Provide assumptions (and their bases) as to what equipment will displace water resulting in higher pool level:

Water below the 2000' elevation does not contribute to the pool height because these locations are below the reactor containment building floor, consists of the reactor cavity and incore tunnel, and have a volume of 17915 ft^3. Equipment and structures that displace water below the 2000' elevation include incore tubes, incore tunnel beams, and the reactor vessel. Above the 2000' elevation level the pool level is affected by pressurizer relief tank (PRT) supports, reactor coolant drain tank (RCDT) supports, recirculation sump curbs, incore sump curbs, and the incore tunnel. Concrete walls and raised floors also affect the minimum pool level in containment. Below is a summary of the equipment and structures that displace water volume. Note that pipes and hangers are assumed to displace 0.5% of water volume. This displacement is accounted for in the accumulation rates, but is not shown below.

Equipment below 2000' elevation that displaces water:
Volume Profile (that consists of the reactor cavity and incore tunnel): 17915 ft^3

1. Incore tubes - 30.05 ft^3
2. Reactor vessel - 2078 ft^3
3. Incore tunnel beams - 21.9 ft^3

Equipment between elevation 2000'-0" and 2000'-6" that displaces water:
Volume Profile: 7,698.5 ft^3

1. Concrete walls - 1535.5 ft^3
2. Floor at 2001'-4" - 2355 ft^3
3. PRT supports – 18.4 ft^3
4. RCDT supports – 2.78 ft^3
5. Recirculation sump curbs – 16.9 ft^3
6. Incore sump curbs – 9.45 ft^3
7. Area of incore tunnel – 94.3 ft^3
8. Accumulator Base Plates – 36.8ft^3

Equipment between elevation 2000'-6" and 2001'-4" that displaces water:
Volume Profile: 12,777 ft^3

1. Concrete walls - 2549 ft^3
2. Floor @ 2001'-4" - 3909 ft^3
3. PRT supports – 30.4 ft^3
4. RCDT supports – 24.6 ft^3
5. Incore sump curbs – 15.7 ft^3
6. Area of incore tunnel – 156.5 ft^3

Accumulation Rate:

Equipment between elevation 2001'-4" and 2001'-10" that displaces water:
Volume Profile: 7,698.5 ft^3

1. Concrete walls - 1535.5 ft^3
2. SG and RCP Base Plates – 84 ft^3
3. PRT supports – 18.4 ft^3
4. Incore sump curbs – 9.45 ft^3
5. Area of incore tunnel – 94.3 ft^3

Above 2001'-10", the water level will only be displaced by concrete walls. The area profile will increase by 92 ft^2 with the additional space of the reactor annulus. This along with the 0.5% volume displacement of pipes and hangers will result in an accumulation rate of 12,353 ft^3/ft above this level.

Response to 3.g.12. Provide assumptions (and their bases) as to what water sources provide pool volume and how much volume is from each source:

The initial RCS volume is minimized by assuming a minimum pressurizer volume of 38%. This assumption is based on the nominal pressurizer span at 100% power and Tavg = 570.7°F.

The RWST, RCS and the SI accumulator inventory was assumed to be the same density.as pure water. This assumption is reasonable since the boric acid concentrations are small.

To conservatively minimize the mass of water contained in the SI accumulators that could flow into the containment building, the temperature is assumed to be equal to the maximum initial containment air temperature of 120°F, consistent with the accident analysis. This approach is conservative because the density of water decreases with increasing temperature.

Mass input to sump from the containment water level calculation at ECCS switchover (or RHR swapover) accident scenario is:

- RCS blowdown 551,068 lbm
- SI accumulators 199,996 lbm
- Initial containment vapor 732 lbm
- RWST input 1,882,666 lbm

Response to 3.g.13. If credit is taken for containment accident pressure in determining available NPSH, provide description of the calculation of containment accident pressure used in determining the available NPSH:

Credit is not taken for containment accident pressure in determining available NPSH. (Containment accident pressure corresponding to the vapor pressure at the sump liquid temperature was credited for potential for flashing evaluations as stated in the response to Issue 3.f.14, but not for available NPSH.)

Response to 3.g.14. Provide assumptions made which minimize the containment accident pressure and maximize the sump water temperature:

Credit is not taken for containment accident pressure in determining available NPSH. (Containment accident pressure corresponding to the vapor pressure at the sump liquid temperature was credited for potential for flashing evaluations as stated in the response to Issue 3.f.14, but not for available NPSH.)

Response to 3.g.15. Specify whether the containment accident pressure is set at the vapor pressure corresponding to the sump liquid temperature:

For temperature above 212 °F the containment accident pressure is set equal to the vapor pressure corresponding to the sump liquid temperature. For temperatures below 212 °F containment accident pressure is not credited, and containment pressure is set equal to 14.7 psia.

Response to 3.g.16. Provide the NPSH margin results for pumps taking suction from the sump in recirculation mode:

NPSH margins for pumps taking suction from the sump in recirculation mode at the limiting instance, 212 °F (see the response to Issue 3.g.2 for more details), are presented in Table 3.g-1.

Table 3.g-1: NPSH Margin Results at 212 °F

Pump	NPSH Margin (ft)
RHR	2.8
CS	2.1

3.h. 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.

1. *Provide a summary of type(s) of coating systems used in containment, e.g., Carboline CZ 11 Inorganic Zinc primer, Ameron 90 epoxy finish coat.*
2. *Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis.*
3. *Discuss suction strainer head loss testing performed as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris.*
4. *Provide bases for the choice of surrogates.*
5. *Describe and provide bases for coatings debris generation assumptions. For example, describe how the quantity of paint debris was determined based on ZOI size for qualified and unqualified coatings.*
6. *Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions.*
7. *Describe any ongoing containment coating condition assessment program.*

The information in this section revises information previously provided by Ameren Missouri to GL 2004-02, section 3.h. (Reference [2]). The coatings evaluation described below conform to sections 3.4.2.1 and 3.4.3 of NEI 04-07, Vol. 2 SE (Reference [1]).

Response to 3.h.1. Provide a summary of type(s) of coating systems used in containment, e.g., Carboline CZ 11 Inorganic Zinc primer, Ameron 90 epoxy finish coat:

The definition of a DBA qualified coating used at Callaway is:

A coating system used inside reactor containment that can be attested to having passed the required laboratory testing, including irradiation and simulated DBA, and has adequate quality documentation to support its use as DBA qualified. This applies to all coating systems, epoxy or otherwise, that are used inside the reactor containment building.

The qualified coatings inside the reactor containment are detailed in Callaway calculations and specifications. There are various types of qualified coatings used in the containment including epoxy and IOZ systems.

- Carboline 195 primer with Carboline 191 HB finish is an epoxy system used to coat concrete walls, ceilings, and floors as well as accumulators, RCP, and HXR.
- Ameron Dimetcote 6 or Carboline CZ-11 SG as a primer with Ameron 90 finish are IOZ systems used to coat containment liner plates or structural steel respectively.

Any coating that does not satisfy the above definition is classified as an unqualified coating.

The unqualified coatings inside the reactor containment are detailed in Callaway calculations. There are various types of unqualified coatings used in the containment including acrylic, alkyd, epoxy systems, IOZ, and varnish.

- Carboline 890 and Carboline 193 LF are epoxy coatings used in containment on steel surfaces. Also, Carboline 890 is used as a service level 1 coating inside containment.
- Alkyd coatings are oil based paints used on various components such as valves, actuators and equipment. Benjamin Moore® “Ironclad” is a coating on pipe elbows specified as an alkyd within Callaway.
- Dimetcote is an IOZ silicate coating on the exterior of the reactor coolant pump (RCP) motors.
- Varnish is found throughout containment on several cooling fan motors as an original equipment manufacturer (OEM) primer coat for epoxy.

Response to 3.h.2. Describe and provide bases for assumptions made in post-LOCA paint debris transport analysis:

Debris transport is determined at four break locations. The maximum transport fraction for each material’s constituent is applied for analysis and is presented below.

Unqualified coatings are assumed to fail as 10 micron particulate and have a transport fraction of 100%.

Qualified coatings are assumed to fail as 10 micron particulate and have a transport fraction of 99%. The only credit applied is pool fill transport.

Degraded qualified coatings vary in size and transport as displayed in Table 3.h-1. The amount of mass for each size is also presented in Table 3.h-1. Blowdown, washdown, and pool fill transport do not influence degraded qualified coatings. For damaged coatings, holdup is not credited during blowdown, washdown, or recirculation. The transport fraction for these stages is 100%. During pool fill, a portion of qualified coatings debris are expected to be pushed by sheet flow to inactive cavities and the emergency sump strainers. One percent of destroyed qualified coatings are estimated to transport to inactive cavities. The overall transport fraction accounts for all transport stages but is finally equivalent to the pool-fill transport fraction, 1 x 1 x 1 x 0.99 = 0.99.

Table 3.h-1: Degraded Qualified Coatings Sizes, Percent Mass, and Transport Fractions.

Description	Size	% by Mass	Transport Fraction
Fines	< 1/8”	49.51	100%
Flat Small Chips	1/8” to 1/4”	5.02	6%
	1/4” to 1/2”	4.41	
Flat Large Chips	1/2” to 2”	20.53	4%
Curled Chips	1/2” to 2”	20.53	100%

Response to 3.h.3. Discuss suction strainer head loss testing performed as it relates to both qualified and unqualified coatings and what surrogate material was used to simulate coatings debris:

Strainer head loss testing was conducted in 2016 to demonstrate acceptable performance with the design basis particulate debris loading. Quantities for strainer head loss testing were based on a scaling factor derived from the test module size relative to the total strainer size less miscellaneous debris. To conserve the number of particulates, the scaling factor was applied to the volumes of debris predicted to be transported to the strainer. Silica sand (AGSCO 70) and ground silica (Sil-Co-Sil 53 and Min-U-Sil 5) were used as surrogate materials for the containment qualified, unqualified, and degraded qualified coatings. For degraded qualified coatings a particulate surrogate was used in lieu of chips because typically, particulates induce a greater head loss and, unlike chips, particulates will not disrupt a contiguous debris bed, which would reduce the head loss.

Response to 3.h.4. Provide bases for the choice of surrogates:

The basis for surrogate selection was to have a similar size distribution to the risk-informed pilot plant, which was accomplished by using 26% Min-U-Sil 5, 37% Sil-Co-Sil 53, and 37% AGSCO 70. Figure 3.h.1 compares the size distributions of Callaway and the risk-informed pilot plant with a cumulative distribution function. Since all three surrogates have identical material densities, the volume fraction distribution is identical to the mass distribution.

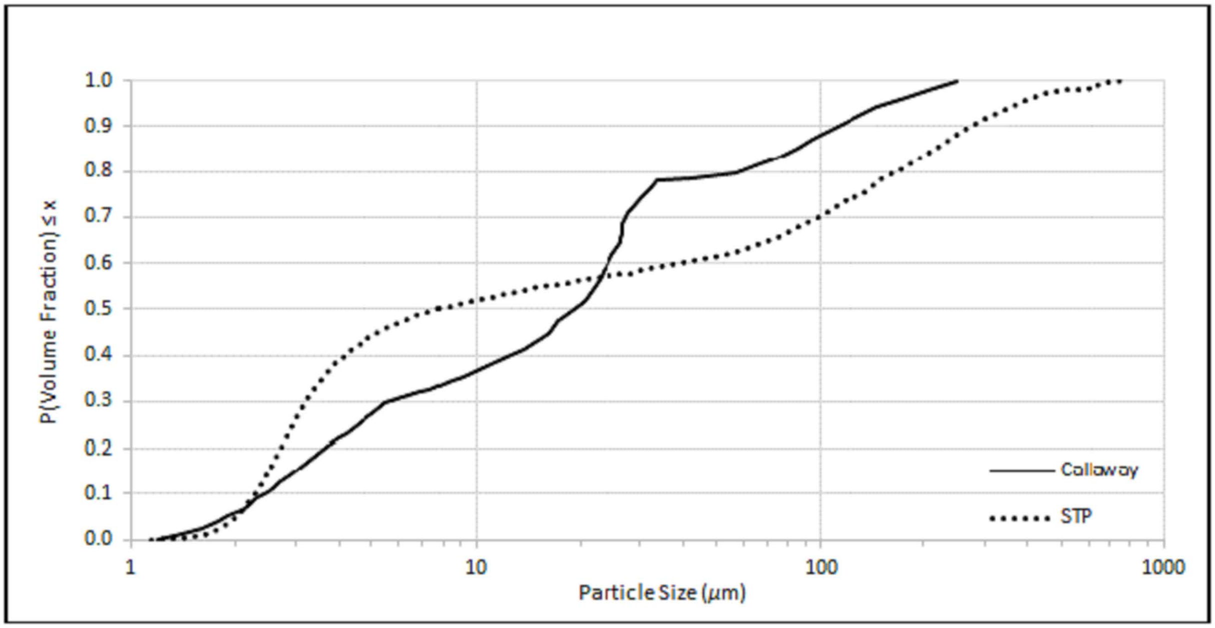


Figure 3.h.1: Comparison of Particle Size Distribution for Callaway and the Risk-Informed Pilot Plant

Response to 3.h.5. Describe and provide bases for coatings debris generation assumptions. For example, describe how the quantity of paint debris was determined based on ZOI size for qualified and unqualified coatings:

The following attributes provide the basis for coatings debris generation assumptions and the determination of the quantities of coatings generated during an event, while adhering to regulatory guidance.

<u>Qualified Coatings</u>

ZOI sizes for qualified coating systems are based on WCAP-16568-P jet impingement testing data and staff guidance regarding coatings evaluation (Reference [7]). Qualified coating systems with an epoxy topcoat are analyzed with a 4D ZOI. Qualified coating systems that have exposed IOZ are analyzed with a 10D ZOI [5]. All qualified coatings are assumed to fail as 10 micron particulate.

Per NEI 04-07, qualified coatings within the ZOI are assumed to fail as a result of impingement and post-accident environmental conditions. Qualified coatings outside the ZOI are assumed to remain intact. To determine the amount of qualified coatings that fail, a three-dimensional model of the containment was constructed to model the geometric orientation of all qualified coatings in relation to possible LOCA initiating welds. CASA Grande was used to simulate all potential breaks and to calculate the areas of specific surfaces (i.e. floors, walls, equipment, etc.) within each ZOI. Plant documentation identifying coating types and applications (i.e. coating dry film thickness) were also incorporated to CASA Grande to calculate the associated volume of qualified coatings. The qualified coating volumes and dry film densities were used to determine the qualified coating masses.

Coating systems applied in the model for concrete are the systems that generated the most debris based on mass per surface area. The coating system containing Dimetcote is used on the steel liner plate, while the system containing Carboline CZ-11SG is used for structural steel. Also, the amount of qualified coatings in the model matches the qualified coatings schedule. Table 3.h.2 displays details of the qualified coating systems.

Table 3.h.2: Coating Systems Assumed for Debris Generation

Coating System Number	Surface Type	Coating Name	Coating Type	Dry Film Density (lbm/ft3)	Dry Film Thickness (mils)
100, 102	Concrete Walls and Ceilings	Carboline 195 Carboline 191 HB	Epoxy	107.97 104.6	20 6
103	Concrete Floors	Carboline 195 Carboline 191 HB	Epoxy	107.97 104.6	20 12
104	Steel	Ameron D6 (Liner Plate) Ameron 90	IOZ	300 117.3	4 6
		Carboline CZ-11SG (Structural Steel) Ameron 90	IOZ	214.3 117.3	4 6

During a plant inspection, rust formation was discovered on the GN-050 HBC pipes that are part of the HVAC system. Since this rust is located under jacketed fiberglass insulation, it is not considered to contribute to debris generation or chemical effects post-LOCA unless the insulation covering it also breaks. Therefore, the rust uses a 17D ZOI size, like the LDFG covering it. The thickness of this rust was ultrasonically measured in six different locations and the average thickness of 0.1 inch was used in quantifying the rust. The density of rust is 320 lbm/ft^3. Also, rust was assumed to be destroyed as 10 micron particulate.

<u>Unqualified Coatings</u>

Per NEI 04-07 all unqualified coatings inside and outside a ZOI are assumed to fail as a result of impingement and post-accident environmental conditions. Amounts of unqualified coatings that fail were determined in a similar manner to qualified coatings. Plant unqualified coatings document describe location, coating, dry film thickness, and surface area. The dry film densities are determined by theoretical coating spread rates (sq. ft. per gallon at 1-mil thickness) that require liquid density, shipping weight, and percent solids instead of specific vendor coating spread rates. Specific coatings are unknown from some alkyds and epoxies. Unknown alkyds implemented properties from NEI guidance. Unknown epoxies were assumed to be unqualified Carboline 890, which was commonly used at Callaway.

The total unqualified coatings mass of acrylic, alkyd, epoxy and IOZ fail as 10 µm particulate, contribute to every break scenario, and transport to the strainer at 100%. This follows the NRC guidance. The total mass of unqualified coatings is approximately 4190 lbm; see Table 3.h-3 for more details regarding unqualified coatings quantities.

Table 3.h-3: Unqualified Coatings Quantities

Coating Type	Mass (lb)	Volume (ft^3)
Acrylic (Carboline 3359)	31.392	0.463
Alkyd (Generic)	95.158	0.971
Alkyd (Benj. Moore® Ironclad)	0.128	0.001
Epoxy (Generic)	910.752	7.160
Epoxy (Carboline 193 LF)	514.934	4.210
Epoxy (Carboline 191 HB)	590.362	5.644
IOZ (Carbozinc 11)	673.545	3.143
IOZ (Dimetcote)	780.000	2.600
IOZ (Generic)	570.468	2.662
Varnish (FD Heat Resistant)	17.72	0.215
Total in the Recirculation Pool	4184	27

<u>Degraded Qualified Coating</u>

A degraded qualified coating is a qualified coating that degraded over time and has test data to support failure characteristics. Tests performed for Comanche Peak Steam Electric Station by Keeler & Long (Reference [15]) has been reviewed and found applicable to the degraded DBA-qualified epoxy and inorganic zinc coatings applied at Callaway. In the test, an epoxy topcoat and inorganic zinc primer coating system that degraded was removed from the Comanche Peak Unit 1 containment after 15 years of nuclear service. The removed coating was subjected to DBA conditions in accordance with ASTM D 3911 03. In addition to the standard test protocol contained in ASTM D 3911 03, 10 ppm filters were installed to capture debris generated during the test.

Data in this report shows that inorganic zinc predominantly fails in a size range from 9 to 89 microns with the majority being between 14 and 40 microns. Therefore, a conservative size of 10 microns was assumed for transport and head loss tests of inorganic zinc. Data in this report also showed that DBA-qualified epoxy (Carboline Phenoline 305) that has failed as chips by delamination tend to remain as chips in a LOCA environment. Almost all of the chips remained larger than 1/32-inch diameter. Consistent with manufacturer's published data sheets and material safety data sheets, Carboline Phenoline 305 is representative of the other DBA qualified epoxy coatings found in U.S. nuclear power plants (Reference [15]). This includes Carboline 890 epoxy coating in Callaway's containment.

Degraded qualified coatings contribute debris to every break scenario. Carboline 890 is the only degraded qualified coating in Callaway. The size and mass distribution of the degraded qualified Carboline 890 epoxy is provided in Table 3.h-4 and follows NRC guidance (Reference [16]). If the degraded qualified epoxy has an IOZ primer, the IOZ primer is assumed to fail as 10 micron particulate based on Keeler & Long Report 06-0413 (Reference [15]).

Table 3.h-4: Degraded Qualified Coating Carboline 890 Epoxy Debris Details

Description	Size	% by Mass	Mass, lbm
Fines	< 1/8”	49.51	128.57
Flat Small Chips	1/8” to 1/4”	5.02	13.039
	1/4” to 1/2”	4.41	11.455
Flat Large Chips	1/2” to 2”	20.53	53.351
Curled Chips	1/2” to 2”	20.53	53.351

Response to 3.h.6. Describe what debris characteristics were assumed, i.e., chips, particulate, size distribution and provide bases for the assumptions:

Per NRC guidance all qualified and unqualified coatings were assumed to fail as 10 micron particulate, and degraded qualified epoxy coatings were assumed to fail with the size distribution presented in Table 3.h-4.

Response to 3.h.7. Describe any ongoing containment coating condition assessment program:

Coating condition assessments are conducted as part of the structures monitoring program and conducted, at a minimum, once each fuel cycle in accordance with plant procedures and preventative maintenance documents. Monitoring involves conducting a general visual examination of all accessible coated surfaces within the containment building and is intended to characterize the condition of the coating systems. If determined to be necessary, additional nondestructive and destructive examinations of degraded coating areas will be conducted as specified by the plant Protective Coatings Specialist. If localized areas of degraded coatings are identified, those areas are evaluated and scheduled for repair/replacement as necessary.

Examinations of degraded coating areas are conducted by qualified personnel as defined in plant procedures as recommended by ASTM D 5163 05a. Detailed instructions on conducting coating examinations, including deficiency reporting criteria and documentation requirements are delineated in plant procedures and preventative maintenance documents.

3.i. 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.

Provide the information requested in GL 04-02 Requested Information Item 2.(f) regarding programmatic controls taken to limit debris sources in containment.

> *GL 2004-02 Requested Information Item 2(f)*
> *A description of the existing or planned programmatic controls that will ensure that potential sources of debris introduced into containment (e.g., insulations, signs, coatings, and foreign materials) will be assessed for potential adverse effects on the ECCS and CSS recirculation functions. Addressees may reference their responses to GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment," to the extent that their responses address these specific foreign material control issues.*

In responding to GL 2004 Requested Information Item 2(f), provide the following:

1) *A summary of the containment housekeeping programmatic controls in place to control or reduce the latent debris burden. Specifically for RMI/low-fiber plants, provide a description of programmatic controls to maintain the latent debris fiber source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fiber debris remain valid.*
2) *A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment.*
3) *A description of how permanent plant changes inside containment are programmatically controlled so as to not change the analytical assumptions and numerical inputs of the licensee analyses supporting the conclusion that the reactor plant remains in compliance with 10 CFR 50.46 and related regulatory requirements.*
4) *A description of how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65.*

If any of the following suggested design and operational refinements given in the guidance report (guidance report, section 5) and SE (SE, section 5.1) were used, summarize the application of the refinements.

5) *Recent or planned insulation change-outs in the containment which will reduce the debris burden at the sump strainers*

6) *Any actions taken to modify existing insulation (e.g., jacketing or banding) to reduce the debris burden at the sump strainers*
7) *Modifications to equipment or systems conducted to reduce the debris burden at the sump strainers*
8) *Actions taken to modify or improve the containment coatings program*

Response to 3.i.1. A summary of the containment housekeeping programmatic controls in place to control or reduce the latent debris burden. Specifically for RMI/low-fiber plants, provide a description of programmatic controls to maintain the latent debris fiber source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fiber debris remain valid:

Housekeeping and foreign material exclusion program procedures have been revised to target the containment cleaning effort from the results of the swipe sampling survey and to enhance the containment cleanliness requirements in Modes 1 through 4.

Response to 3.i.2. A summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment:

Callaway procedurally tracks all transient materials taken inside containment during modes 1 through 4. Prior to entry into mode 4, containment cleanliness is established by performing and documenting a visual inspection of the containment for loose debris. During normal operations, all items taken into containment are logged. At the completion of the containment entry the items are accounted for. At the completion of work activities inside containment during normal operations, the work area is thoroughly cleaned and inspected (including the area below the work activity, if the work was performed on grating), prior to leaving containment.

Response to 3.i.3. A description of how permanent plant changes inside containment are programmatically controlled so as to not change the analytical assumptions and numerical inputs of the licensee analyses supporting the conclusion that the reactor plant remains in compliance with 10 CFR 50.46 and related regulatory requirements:

Engineering Design Guide ME-012 provides guidance for containment sump blockage concerns for design changes inside containment. New components or replacement components must have a qualified coating. Any material that is to be added to containment must be evaluated to determine if the potential exists to create debris that could end up at the strainers. Deviations from the guidance are permitted but must be evaluated by an engineer cognizant of GSI-191 and be explained in the change package.

In addition to the design change controls, Callaway procedurally tracks all transient materials taken inside containment during modes 1 through 4. During normal operations, all items taken into containment are logged. At the completion of the containment entry the items are accounted for. At the completion of work activities inside containment during normal operations, the work area is thoroughly cleaned and inspected (including the area below the work activity, if the work was performed on grating), prior to leaving containment.

Response to 3.i.4. A description of how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65:

Procedures are in place to control maintenance activities and evaluate temporary changes that have the potential to affect the debris source term.

The containment entry procedures contain requirements for control of materials during work activities conducted in the containment building during modes 1 through 4. Following maintenance activities in the containment building, procedures that control the containment cleanliness verification process specifically require both general area and target area cleaning.

Changes implemented as temporary alterations in support of maintenance that impact plant design are required to be developed in accordance with the same design change procedures that are used for all plant modifications. As described in section 2, the plant modification procedures contain administrative controls that specifically address potential impacts of debris on the ECCS performance.

Response to 3.i.5. Recent or planned insulation change-outs in the containment which will reduce the debris burden at the sump strainers:

During Refueling Outage XIV, replacement SGs were installed. The replacement SGs were furnished with RMI, which replaced the jacketed NUKON® insulation that had been previously installed. The installation of RMI on the replacement SGs is presently accounted for in the debris source term. There are no forthcoming planned insulation change-outs that would reduce the debris burden at the sump strainers.

Response to 3.i.6. Any actions taken to modify existing insulation (e.g., jacketing or banding) to reduce the debris burden at the sump strainers:

There are no planned actions to modify existing insulation (e.g., jacketing or banding) to reduce the debris burden at the sump strainers.

Response to 3.i.7. Modifications to equipment or systems conducted to reduce the debris burden at the sump strainers:

There are no planned modifications to equipment or systems to reduce the debris burden at the sump strainers.

Response to 3.i.8. Actions taken to modify or improve the containment coatings program:

There are no planned actions to modify the existing containment coatings to reduce the debris burden at the sump strainers.

3.j. Screen Modification Package

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

1. *Provide a description of the major features of the sump screen design modification.*
2. *Provide a list of any modifications, such as reroute of piping and other components, relocation of supports, addition of whip restraints and missile shields, etc., necessitated by the sump strainer modifications.*

Response to 3.j.1. Provide a description of the major features of the sump screen design modification:

New sump strainers were installed in the two containment Recirculation Sumps during Callaway Refueling Outage XV. The PCI Sure-Flow^{TM} Strainers were installed in the sump pits to accommodate the post-accident containment water levels. Figure 3.j-1 shows an isometric view of the location of the sumps in the containment building below two SI accumulator tanks located in the lower left portion of the figure. Figure 3.j-2 shows a closer view of the sump pits.

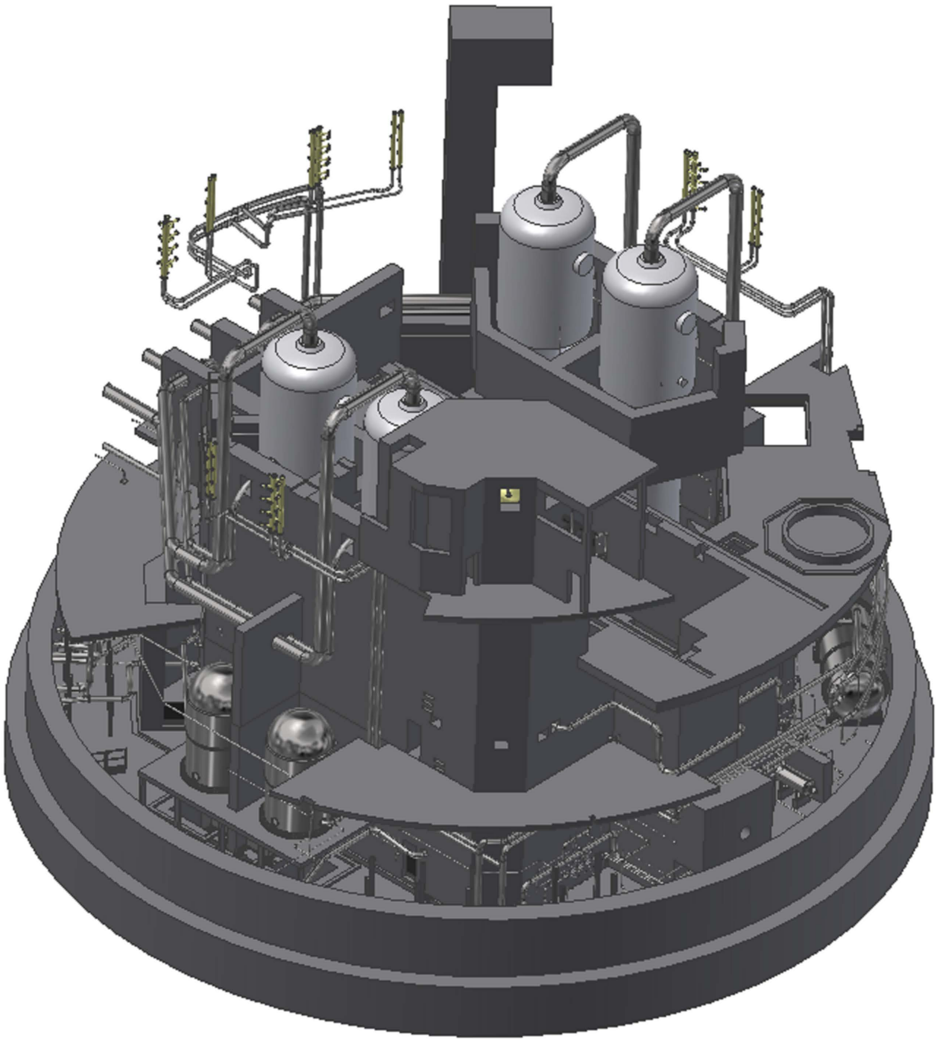


Figure 3.j-1: Isometric View of Lower Containment

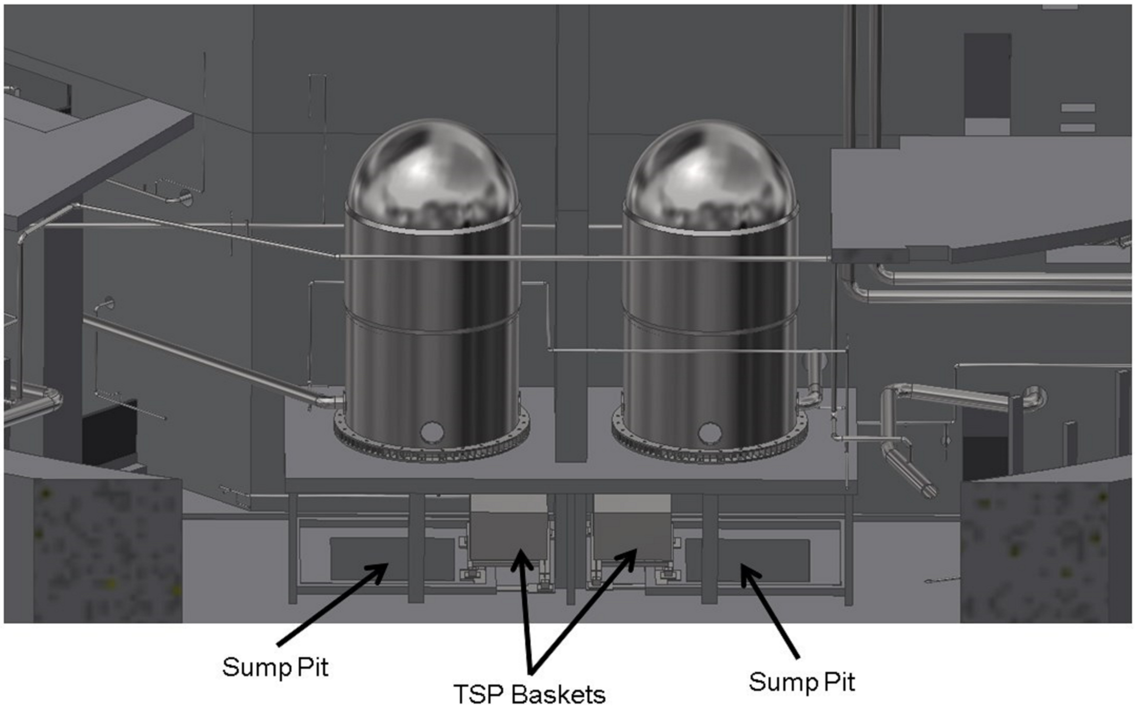
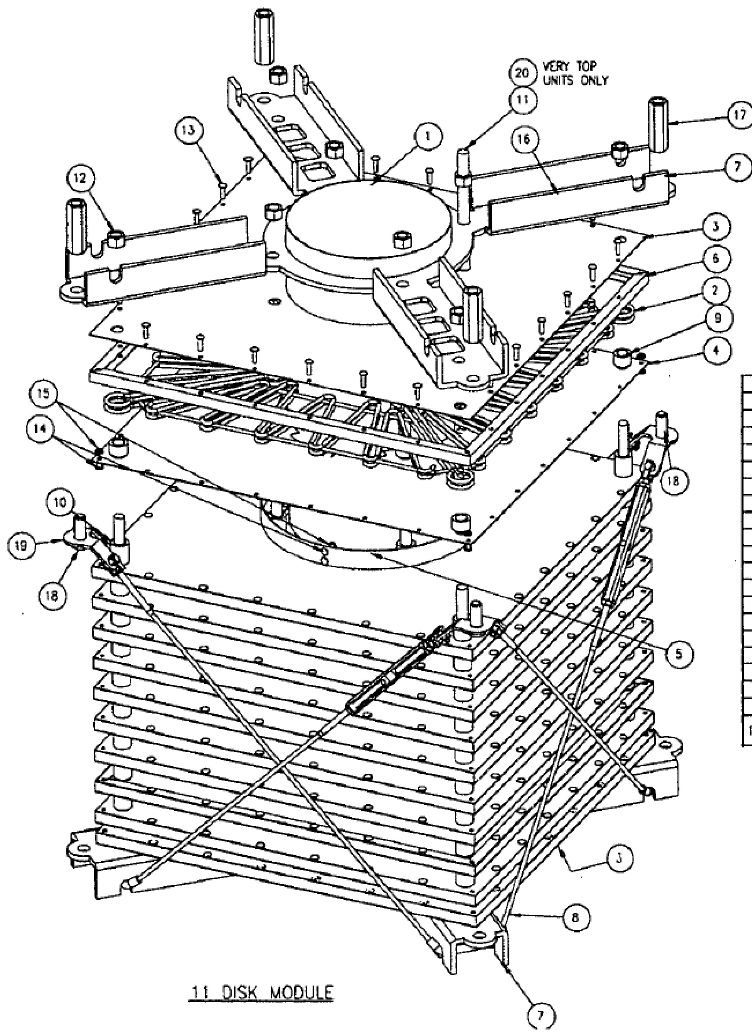


Figure 3.j-2: Close-Up View of Lower Containment

Each new sump strainer is made up of 72 modules. Eight modules are seven plate/disks high and 64 modules are eleven plates/disks high (Refer to Figure 3.j-3). The modules are arranged in a square matrix of 16 modules on each level, except for the bottom level that has only eight modules (Refer to Figures 3.j-4 and 3.j-5). Each stack of modules (see Figure 3.j-5) is an integrated unit that equalizes the flow rate and corresponding pressure drop across the perforated plate at each level and allows for a distributed pressure drop across the column. The strainers are installed on a strainer substructure assembly, which is installed at the bottom of the containment recirculation sump pit. The strainers superstructure consists of four vertical supports on the 2000' elevation concrete pad. These supports are inside the sumps 6-inch concrete curb. A series of horizontal channels connect to the four vertical supports and provide lateral restraint for the module stacks. The strainers are robust so as to also serve as the trash racks, as described in the license amendment application (Reference 23 and 30). The strainers have 0.045-inch holes in the perforated stainless-steel plate surfaces. The materials for the strainer supports, both the lower support platform and the superstructure, are also stainless steel.



ITEM No.	DESCRIPTION
20	TENSION ROD-LONG, 1/2"ø-13UNC x 18 3/4" LG., SS
19	SEISMIC CABLE BRACKET, 11ga., SS
18	BOLTS, 1/2"-13 UNC X 1 1/4", SS
17	COUPLING 1/2-13UNC X 2 1/2" LG. SS
16	I.D. TAG, SS
15	BACKER WASHER, SS
14	3/16"ø, CLOSED END RIVETS W/ GRIP RANGE OF 0.020"-0.125", SS
13	3/16"ø, OPEN END, BLIND RIVETS W/ GRIP RANGE OF 0.626"-0.75", SS
12	HEAVY HEX NUT, 1/2"-13 UNC, SS
11	TENSION ROD, 1/2"ø-13UNC x 18 1/8" LG., SS
10	SPACER, 1" x 1/2"ø SCH 80, SS PIPE
9	SPACER, 1/2" x 1/2"ø SCH 80, SS PIPE
8	SEISMIC CABLE ASSEMBLY, SS
7	EXTERNAL RADIAL/DEBRIS STOP, 1/4" THK., SS
6	RIM DISK, 22ga. PERF PLATE, SS
5	GAP DISK, 22ga. PERF PLATE, SS
4	INTERMEDIATE DISK FACE, 22ga. PERF PLATE, SS
3	FIRST & LAST DISK FACE, 22ga. PERF PLATE, SS
2	GRILL, MAD OF 7 ga. & 8 ga. WIRES, SS
1	CORE TUBE, 7.5"ø, 16 ga., SS

Figure 3.j-3: 11 Disk Sump Strainer Module Detail

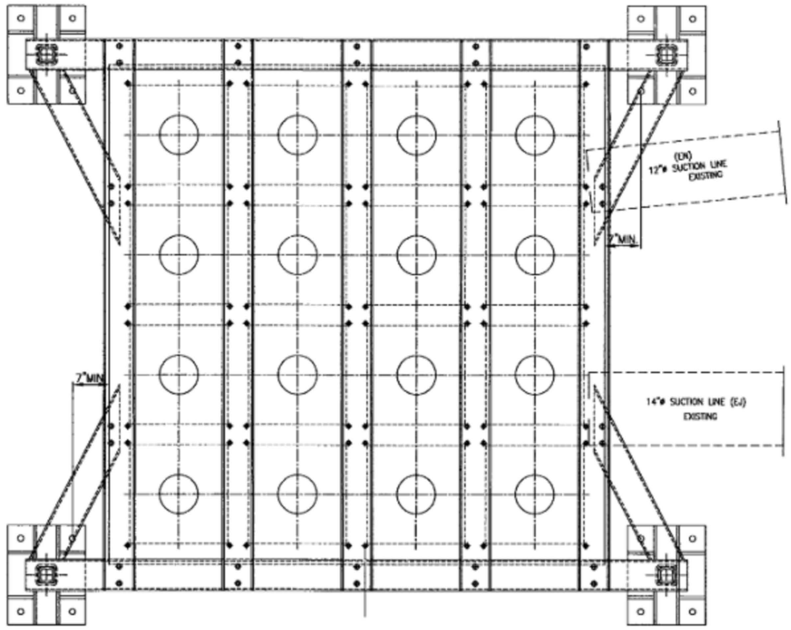


Figure 3.j-4: 11 Sump Strainer Plan View

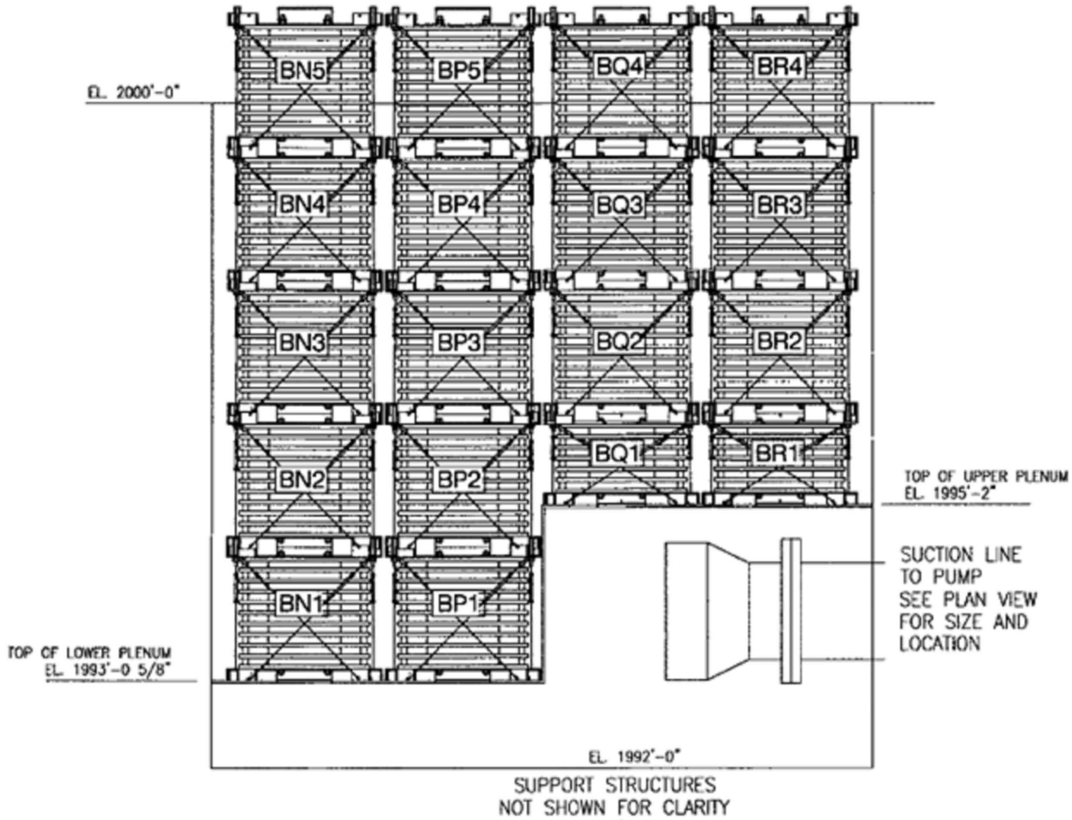


Figure 3.j-5: 11 Disk Sump Strainer Section Detail

The original containment recirculation sump screens and trash racks had approximately 200 ft^2 of effective surface area per sump. The new replacement sump strainers have approximately 3300 ft^2 of effective surface area per sump that can handle the amount of debris generated and carried to the sumps. A significant design feature of the new PCI Sure-Flow® strainers ensures uniform flow rate through all sections of the modules. This ensures that during post-accident operation, debris is not preferentially distributed to certain areas of the strainer. Additionally, as a result of the increased surface area, the approach velocity of the recirculation coolant flow at the sump strainer face will be less than 0.01 ft/s.

Response to 3.j.2. Provide a list of any modifications, such as reroute of piping and other components, relocation of supports, addition of whip restraints and missile shields, etc., necessitated by the sump strainer modifications:

As mentioned in section 3.e.4 above, debris barriers have been installed in all openings through the secondary shield wall near the emergency recirculation sumps. The barriers prevent the flow of debris-laden fluid directly to the sumps and force the fluid to take a "long path" through shield wall openings farther away from the sumps. Using perforated plates with a hole size of 1/8 inch, the debris barriers are designed to restrict passage of debris while allowing water to pass through the barrier. While not specifically credited in the debris transport analysis, the effect of any water flow through the "A" and "D" debris will lower pool velocity out the "B" and "C" loop openings. This is conservative compared to the current transport analysis which assumes all water flows out the "B" and "C" loop openings. Debris barriers have been installed in the Loop A and Loop D passageway entrances through the secondary shield wall, as well as in drain trenches and other openings in the secondary shield wall near the sumps. Blockage of small and large piece debris through Loop A and Loop D passageways and other openings was included in the transport modeling.

Based on the interference with the new containment recirculation sump strainers, two additional changes were necessary. These changes were relocation of the trisodium phosphate dodecahydrate (TSP) baskets and modification of the containment recirculation level indication.

During the spring of 1995, Callaway replaced the original active spray additive system, which used sodium hydroxide contained in a spray additive tank as the neutralizing agent, with TSP. The TSP baskets were originally installed inside the original containment sump recirculation screens and placed over the containment sump pit. As a result of the installation of the new containment recirculation sump strainers, these baskets were relocated several feet because their current locations would cause a physical interference with the strainers.

As a result of the new strainer design, the recirculation sump level indication, which resides inside the 6-inch curb surrounding the containment recirculation sump strainers, was relocated and modified. The previous sump level instrumentation was modified by removing the portion of each level instrument that was located inside the containment recirculation sump. This change was considered acceptable since 1) the containment normal sumps provide indication to satisfy post-accident containment sump level indication and 2) the presence of the 6-inch curb surrounding the containment recirculation sumps would not allow indication of containment flooding until at least 6 inches of water was on the containment floor. Note that there is no curb surrounding the two containment normal sumps.

3.k. 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.

Provide the information requested in GL 2004-02 Requested Information Item 2(d)(vii).

GL 2004-02 Requested Information Item 2(d)(vii)
Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions

1. *Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis.*
2. *Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly.*
3. *Summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy line breaks (as applicable).*
4. *If a backflushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow.*

Response to 3.k., Item 2(d)(vii). Verification that the strength of the trash racks is adequate to protect the debris screens from missiles and other large debris. The submittal should also provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions:

The structural evaluation for the replacement strainers, provided by EC-PCI-WC-CAL-6002-6003-1001, concluded that the strainers meet the acceptance criteria for all applicable loadings (i.e. seismic, assumed debris laden operation, and assumed strainer differential pressure). The assumed structural loads were verified to bound the predicted GSI-191 strainer conditions. Also, Callaway does not have trash racks.

Response to 3.k.1. Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer structural analysis:

The sump strainer structural qualification analysis evaluated the strainer modules as well as the supporting structures associated with the strainers. The governing code for qualification of the strainer is the Callaway code of record, the American Institute of Steel Construction (AISC), 7th edition. In circumstances where the AISC code does not provide adequate guidance for the particular component, other codes or standards are used for guidance. The evaluations were performed using a combination of manual calculations and finite element analysis using the GTSTRUDL software and the ANSYS software.

The strainers are designed for the following load combinations:

Seismic loads - The strainers are designed to meet Category I Seismic Criteria. Both the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE) loads are developed from response spectra curves that envelope the response spectra curves for Callaway. The structures are considered "Bolted steel structures" and the damping values for seismic loads are taken from RG 1.61, Rev. 0 as 4% for the OBE and 7% for the SSE.

Live Loads - Live loads include the weight of the debris accumulated on the strainer and the differential pressure across the strainer perforated plates in the operating condition.

Thermal Loads - Thermal expansion is considered in the design and layout of the structures. The strainers are free to expand in the vertical direction as the superstructure is designed with a sliding connection allowing the strainer modules to expand upward without constraint. In the lateral direction, seismic supports are gapped leaving enough space to accommodate the thermal growth of the strainers and their supports without restraint. The design temperature for the strainers is 268°F, which is the maximum calculated containment sump water temperature during a large-break LOCA. The maximum air temperature inside containment can reach as high as 320°F, however this is a very short term spike and the structure would not have time to heat up to this temperature before the containment air temperature would fall back down to lower levels. Therefore, use of the maximum water temperature for material properties and thermal expansion is appropriate.

Hydrodynamic loads - Hydrodynamic loads on the strainers from the motion of the water surrounding the strainer during a seismic event were also considered.

Response to 3.k.2. Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly:

The structural qualification design margins for the various components of the sump strainer structural assembly are listed in Table 3.k-1. At all locations of the structure, the computed stress is less than the associated allowable stress.

Table 3.k-1: Sump Strainer Structural Assembly Components Design Margins

Strainer Component	Interaction Ratio[1]
External Radial Stiffener (including Collar and Plates)	0.15 / 0.79
Tension Rods	0.43 / 0.51
Spacers	0.71 / 0.79
Edge Channels	0.10 / 0.96
Cross Bracing Cables	0.08 / 0.41
Hex Couplings	0.17 / 0.69
Core Tube	0.03 / 0.11
Substructure Angle Iron Support Legs	0.57 / 0.71
Substructure Angle Iron Framing (including coped sections and angle braces)	0.98 / 0.91
Substructure Channels (including coped sections)	0.92 / 0.94
Cover Plates	0.33 / 0.46
Superstructure Square Tubing Support Legs	0.19 / 0.74
Superstructure Channels	0.13 / 0.60
Perforated Plate (DP Case)	0.80 / 0.66
Perforated Plate (Seismic Case)	0.31 / 0.29
Perforated Plate (Inner Gap)	0.972 / 0.9996
Wire Stiffener[2]	0.70
Perforated Plate (Core Tube End Cover DP Case)	0.70 / 0.60
Perforated Plate (Core Tube End Cover Seismic Case)	0.07 / 0.08
Radial Stiffening Spokes of the End Cover Stiffener	0.12 / 0.11
Core Tube End Cover Sleeve	0.08 / 0.05
Weld of Radial Stiffener to Core Tube	0.07 / 0.31

Strainer Component	Interaction Ratio[1]
Weld of mounting tabs to End Cover Stiffener	0.02 / 0.01
Weld of End Cover Stiffener to End Cover Sleeve	0.07 / 0.05
Edge Channel Rivets	0.05 / 0.67
Inner Gap Hoop Rivets	0.09 / 0.08
End Cover Rivets	0.03 / 0.02
Connecting Bolts and Pins	0.50 / 0.63
Mounting Pin Weld	0.43 / 0.80
Substructure Sealing Plates	0.99
Substructure Bolted Connections	0.76 / 0.93
Substructure Welded Connections	0.46 / 0.77
Substructure Post Jack Bolt and Baseplate	0.63 / 0.71
Substructure Wall Jack Bolts	0.39 / 0.39
Superstructure Bolted Connections	0.08 / 0.79
Superstructure Welded Connections	0.22 / 0.82
Superstructure Expansion Anchors[3]	0.15 / 0.88 / 0.64
Superstructure Anchor Base Plate[3]	0.16 / 0.64 / 0.76
Superstructure Anchor Base Plate Stiffener Welds[3]	0.18 / 0.76 / 0.40

[1] Interaction Ratio, i.e., the calculated stress divided by the allowable stress. Listed as OBE/SSE cases unless noted otherwise.
[2] DP loads only
[3] Worst case OBE/SSE for ShearX, ShearY, and Tension

The assumed GSI-191 inputs to the structural evaluation are compared to ensure the assumed loads bound the predicted results. Table 3.k-2 contains a comparison of the implemented differential pressure for structural evaluations of the strainer versus the maximum differential pressure measured during head loss tests. The comparison shows that the maximum measured differential pressure is less than the implemented differential pressure for structural evaluations at both indicated temperatures.

Table 3.k-2: Sump Strainer Head Loss Margin

Condition	Structural Head Loss Limit, ft-water	Tested Head Loss, ft-water	Head Loss Margin, ft-water
Hot, 268 °F	4.2	4.1	0.1
Cold, 185 °F	5.6	4.2	1.4

Also, the mass of debris implemented in the structural evaluation is compared to the mass of debris predicted to reach the strainers assuming 100% filtrations (all debris is captured by the strainer). Total debris mass implemented as a boundary condition on a single train in the structural analyses is 4330.8 lbm. The maximum amount of debris transported to the strainer for a single LOCA among all examined cases that do not exceed the tested RoverD fiber limit is 5408.3 lbm, which consists of masses displayed in Table 3.k-3. Fiber and qualified coatings are break-dependent debris sources, and 344.5 lbm is the largest amount of break-dependent debris that is transported to a strainer for any individual successful break. Unqualified coatings, latent fiber, latent particulate, and fiber margin masses contribute to every break regardless of size. Chemical load with Largest LDFG Debris Generated with Intact Blankets for RoverD Success Cases is the chemical load with the maximum quantity of LDFG debris generated for successful RoverD cases.

Table 3.k-3: Sump Strainer Debris Loadings

Debris Type	Mass, lbm
Break Dependent Debris (Fiber + Qualified Coatings)	344.5
Unqualified Coatings	4,370.0
Latent Fiber	28.8
Latent Particulate	163.2
Fiber Margin	50.0
Chemical Load with Largest LDFG Debris Generated with Intact Blankets for RoverD Success Cases	451.8

Initial comparison of the maximum transported debris mass associated with all LOCA that pass the tested RoverD fiber limit to the assumed structural mass limit suggests that the analyzed structural load can be exceeded by a maximum of 5408.3 lbm – 4330.8 lbm = 1,077.5 lbm. Recall that all cases exceeding the tested RoverD fiber limit are already relegated to core damage. Thus, any incremental risk caused by seismic-induced LOCA can only be caused by cases having debris beds with less fiber than the RoverD limit, and more total mass than assumed in the mechanical load evaluation. The difficulty is that unqualified coatings present in every break cause the excess load. This initial assessment is mitigated by the following considerations.

If two trains are active, a maximum debris mass of 5408.3/2 = 2704.2 lbm is distributed to each train, and the debris mass on each strainer is bounded by the boundary condition of the structural analysis. Therefore, two-train operation, the dominant system response scenario, is certified by the structural analysis with significant margin.

For single-train operation, the maximum amount of debris possible on the strainer exceeds the debris mass boundary condition without credit for coatings pull tests of Carboline 193LF primer and 191HB topcoat (Reference [17]). Prior to a discussion of pull test results, the history of this coatings system needs to be understood. Carboline 193LF primer and 191HB topcoat were applied with an SP-3 surface preparation method to unprimed structural steel, touch-up of damaged coatings, and small-bore pipes. At the time of application, the coating system and application method were considered qualified. However, tests performed on this coating system by an independent lab showed poor adhesion, and Callaway revised this coating system's classification to "unqualified." In 2018, Callaway performed pull tests at twelve locations with three replicates each for a total of thirty six tests of Carboline 193LF primer and 191HB topcoat to measure adhesion to a substrate. Conclusions from the pull tests are quoted below (Reference [17]).

> All test locations exhibited average adhesion strength in excess of 200 psi, which is the original design requirement stated in ANSI N5.12-1974, Protective Coatings (paints) for the Nuclear Industry. Coating system adhesion strength of greater than 200 psi has, in the past, been correlated to acceptable visual inspection by industry experts as documented in EPRI TR-1019157. This past EPRI research provides the basis for NRC accepted visual coatings inspection of safety-related coatings systems in lieu of containment wide physical testing. Similarly, based on the successful (>200 psi) adhesion test results documented in this evaluation for all tested locations including those acceptable by visual inspection, all steel surfaces coated with the 193LF/191HB coating system and having an acceptable visual inspection per PM16505768 can be assumed to have an adhesion strength greater than 200 psi.
>
> Further the 193LF/191HB system utilized in containment has been shown in past Oak Ridge National Laboratory testing to stay attached during DBA immersion testing, and was only downgraded from a qualified to a non-qualified system based on Bechtel reporting of blistering and poor adhesion during testing at an independent laboratory. The 193LF/191HB system did pass an independent laboratory tensile adhesion test. The

plant-specific results in this report prove adhesion for the Callaway inspection, which combined with the results of Oak Ridge National Lab testing prove DBA LOCA performance. The Carboline 193LF/191HB system applied over a SP-3 cleaned surface will remain on the unqualified coatings log but may be evaluated with improved DBA performance in future evaluations based on this plant-specific testing.

Reclassifications of visually acceptable Carboline 193LF and Carboline 191HB from unqualified coatings to qualified coatings result in a reduction of 1105.3 lbm. Therefore, the total mass predicted to reach a single strainer from the largest inventory LOCA passing the RoverD threshold is 4303.0 lbm, which does not exceed the rated performance of the strainer based on a structural analysis load of 4330.8 lbm. Based on Callaway coatings reclassification, seismic induced loads do not add incremental risk to estimated ΔCDF.

Also, during head-loss tests at Alden Research Laboratories, Callaway strainers withstood 4.2 ft of head loss and total debris introduction of 6339.4 lbm (at plant scale) without any visually observed mechanical defects. Masses introduced to the head-loss test exceed the structural analysis boundary condition by approximately 50%. Since the objective of the head-loss tests was to determine hydraulic success for ECCS pump performance, the plenum holding up the strainers was not modeled and the strainers were not accelerated (shaken) during hydraulic testing.

Based on the preceding justifications, the mass implemented in the structural analysis is deemed bounding to the masses predicted to reach the strainers.

Response to 3.k.3. Summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy line breaks (as applicable):

Locations of the strainers provide significant protection from dynamic effects such as pipe whip, jet impingement, and missile impacts associated with a high-energy line break. The recirculation sump strainers are outside the secondary shield wall and are located inside a pit where approximately 1 ft of the strainers are above the reactor containment building floor. A concrete structure is also approximately 7 ft above the strainers and a concrete wall divides the strainer trains. Structural steel that stabilizes the top of the strainer stacks would also provide protection. Figures 3.k-1, 3.k-2, and 3.k-3 illustrate many of the described features.

Also, high-energy pipes are not located in this region. Therefore, the strainers are not susceptible to damage from pipe whip, jet impingement, or missiles associated with high-energy line breaks.

Figure 3.k-1: Picture of Emergency Sump Strainer A

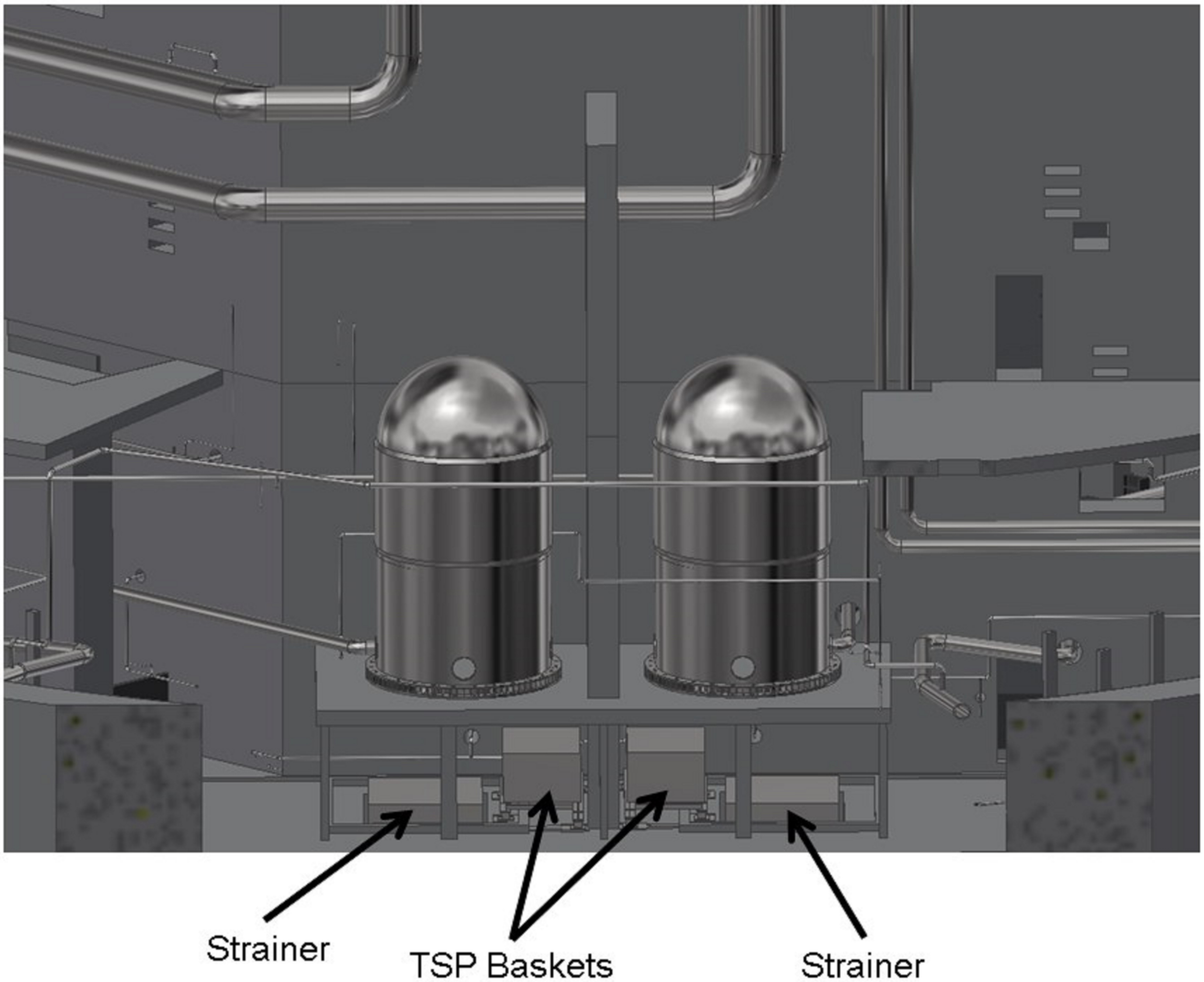


Figure 3.k-2: CAD Picture of Strainer

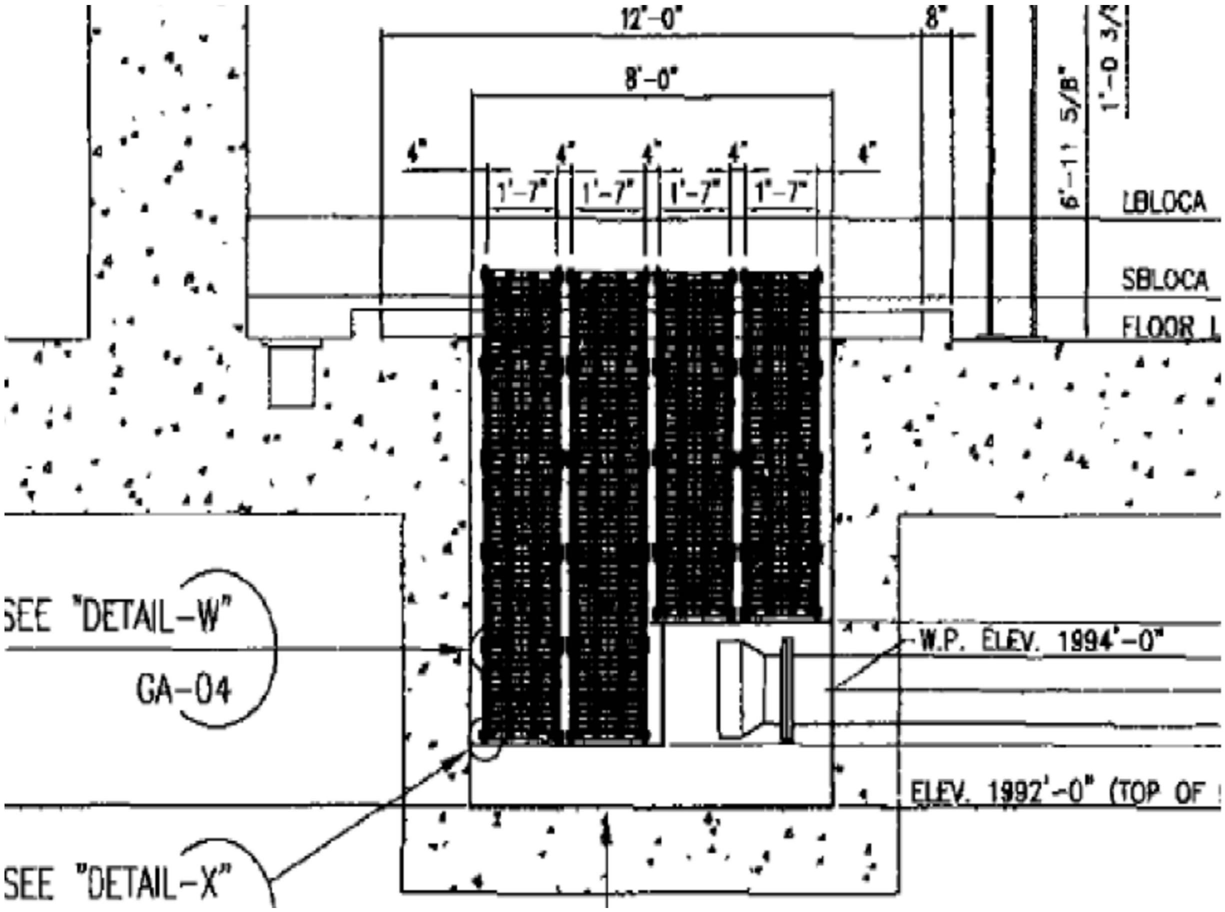


Figure 3.k-3: Drawing with Cross-Sectional of Strainer

Response to 3.k.4. If a back flushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow:

A back flushing strategy is not used for mitigating an excessive strainer head loss condition.

3.I. Upstream Effects

The objective of the upstream effects assessment is to evaluate the flowpaths upstream of the containment sump for holdup of inventory which could reduce flow to and possibly starve the sump.

Provide a summary of the upstream effects evaluation including the information requested in GL 2004-02 Requested Information Item 2(d)(iv).

GL 2004-02 Requested Information Item 2(d)(iv)
The basis for concluding that the water inventory required to ensure adequate ECCS or CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths.

1) *Summarize the evaluation of the flow paths from the postulated break locations and containment spray washdown to identify potential choke points in the flow field upstream of the sump.*
2) *Summarize measures taken to mitigate potential choke points.*
3) *Summarize the evaluation of water holdup at installed curbs and/or debris interceptors.*
4) *Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup.*

The information previously provided by Ameren Missouri to GL 2004-02, of upstream effects evaluation and Requested Information Item 2(d)(iv) (Reference [2]) continues to apply.

Response to 3.I., Item 2(d)(iv). The basis for concluding that the water inventory required to ensure adequate ECCS or CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths

The discussion that follows provides a basis for concluding that water inventory required to ensure adequate ECCS and CSS recirculation would not be held up or diverted by debris blockage at choke-points in containment recirculation sump return flowpaths.

The upstream effects evaluation process described below conforms to section 7.2 of NEI 04-07, Vol. 2 SE (Reference [1]).

Response to 3.I.1. Summarize the evaluation of the flow paths from the postulated break locations and containment spray washdown to identify potential choke points in the flow field upstream of the sump:

The Callaway upstream effects evaluation includes an assessment of the Callaway containment geometry and transport pathways that CS flow and ECCS leakage from the RCS will follow to the lower elevations of the containment building. The evaluation is based upon a review of Callaway design drawings and photographs of inside the containment building.

Each elevation of the containment building was reviewed to identify the physical and structural features that affect the flow of debris and water to the lower elevations of the containment building. The containment building was divided into seven general compartments for individual evaluation separated by grating, concrete walls, and concrete floors.

1. Upper containment including lay down area (elevation 2068'-8" to dome elevation 2205'-0"): Overall the area at this elevation is open with numerous areas of floor grating, which would allow water to pass through to the lower elevations unencumbered. There is one small area of concrete flooring near the pressurizer valve rooms, but water in this location will flow to the grated or open areas surrounding it. This area is open inside and outside the secondary shield walls down to the operating floor at elevation 2047'-6". No potential choke points or hold-up points were identified in this area.

2. Operating floor (elevation 2047'-6"): Overall the area is open inside and outside the SG secondary shield walls to allow water flow to the lower elevations. The area is open inside these secondary shield walls down to elevation 2001'-4" and outside the secondary shield walls down to the operating floor at elevation 2047'-6". No potential choke points were identified at this elevation.

   A hold-up point in this area of the containment building is the reactor head storage and decontamination area. Water collected on the head stand will drain to the surrounding floor but water will be retained by a curb surrounding the head stand. The area inside the curb has a 4-inch floor drain that directs water to a common drain header and then to the drain trenches at the ground floor elevation. However, the drain could become plugged with debris and is not considered functional for this evaluation.

3. Annulus and inside secondary shield (elevation 2026'-0"): Major equipment and features in this area include the main steam and feedwater lines, the tops of the A and D SI accumulators, several HVAC openings, and a compartment for the letdown orifices, the top of which is located at elevation 2036'-0". The northern,

northwestern, and southwestern sides of the annulus have mostly concrete floors while the rest of the elevation outside the secondary shield is grated. There are no curbs associated with the concrete floors, so water inventory will flow to the lower elevations without holdup. No potential choke points or hold-up points were identified at this elevation.

4. Refueling pool (elevation 2009'-9" and elevation 2007'-2"): The refueling pool floor (elevation 2009'-9") contains two 10" drains that are sealed with flanges during refueling operations and are completely open during power operations. There are debris exclusion devices (trash rack cages) installed during power operations to prevent the drain from becoming a choke point. Each debris exclusion device, described in more detail below, is welded to a flange which is bolted to the drain. The flange is approximately 2 inches thick which creates a 2-inch hold-up volume below the flange elevation.

   There is an upending pit below the refueling pool floor elevation at elevation 2007'-2". The drain in the upending pit is a 4-inch line which is normally isolated with a normally closed valve. This area is a hold-up point that would retain water inventory following a postulated design-basis accident (post-DBA). No potential choke points were identified at either of these elevations.

5. Ground floor inside secondary shield (elevation 2001'-4"): There are only four significant openings through which post-DBA recirculation water may pass through the secondary shield wall. These passageways provide personnel and equipment access through the secondary shield wall in an area near each of the four RCPs, and include steps to transition from the 2001'-4" floor elevation inside the secondary shield wall to the 2000'-0" floor elevation outside the wall. Three of the four openings are approximately six feet wide. The fourth opening, entering under the pressurizer near the "D" loop RCP, is approximately 3-feet wide. In Figure 3.I-1, the opening near the "A" loop RCP is shown to the left of the sump pits and the opening near the "D" loop RCP is shown to the right of the sump pits.

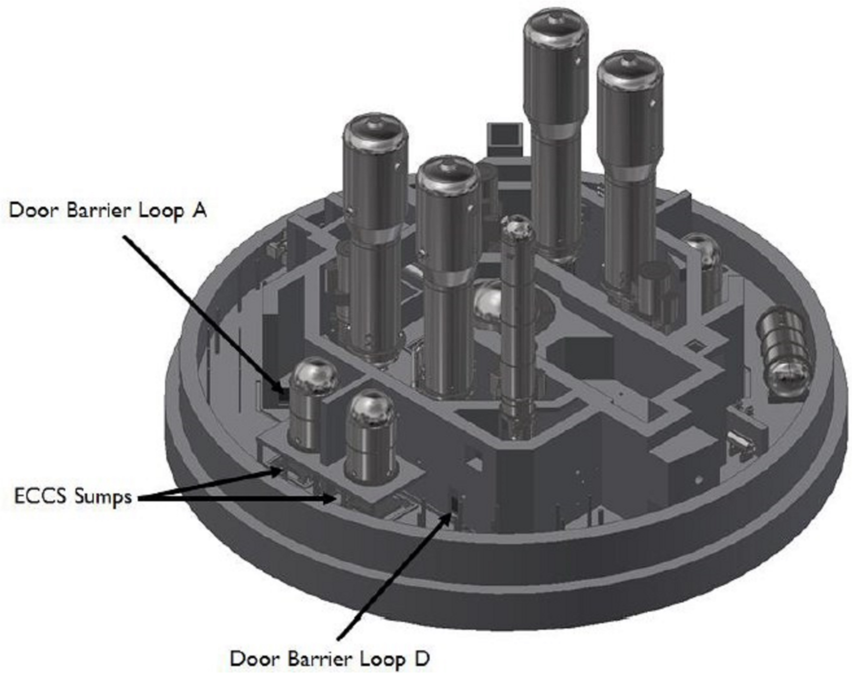


Figure 3.I-1: Isometric View of Sump Pit Area

Additionally, there is a system of small drain trenches, approximately one-foot wide by one-foot deep that surround the primary shield wall and transfer drain water to outside the secondary shield wall. Trenches and drain piping outside the secondary shield walls direct drainage to the normal containment sumps (which are not part of the ECCS) located in the containment ground floor annulus at elevation 2000'-0". Since the containment flood level will exceed the floor elevation inside the secondary shield wall, the trench system is expected to transport water to the containment annulus.

Debris barriers have been installed in the Loop A and Loop D passageway entrances through the secondary shield wall, which are near the containment recirculation sumps. Debris barriers have also been installed in the portions of the drain trenches and other openings in the secondary shield wall that are near the recirculation sumps. The debris barriers at the Loop A and Loop D entrances and the drain trenches are fabricated using perforated plate with 1/8-inch holes to restrict passage of debris while allowing water to pass through the barrier. The barriers prevent the flow of debris laden fluid directly to the sumps and force the fluid to take a "long path" through shield wall openings farther away from the sumps. A portion of the drain trench in the containment annulus region can be seen in Figure 3.I-1, with a trench opening through the secondary shield wall just to the right of the Loop D passageway.

The remaining two open six foot wide passageways through the secondary shield wall will transport the ECCS break flow and CSS flow from inside the secondary shield to the containment annulus without restriction. In addition, the remaining trenches penetrating the secondary shield wall will also pass a significant quantity of water from inside the secondary shield wall to the containment annulus. Given these large passageways and large total trench length, large debris or mounds of debris would not create a choke point or hold-up point preventing the recirculation fluid from transporting to the sump. For added conservatism and ease of analysis, no water flow through the drain trenches is accounted for in the CFD model.

6. Ground floor, annulus (elevation 2000'-0"): The containment building emergency recirculation sumps are also located in this annular region between the secondary shield wall and the containment wall, as shown in Figure 3.I-1. A 6-inch curb surrounds each sump pit, creating a 6-inch deep hold-up volume above the 2000'-0" floor elevation. As discussed above, the normal containment sumps receive water flow from the drain trenches and piping in this area. This represents an additional hold-up volume below the 2000'-0" floor elevation. Given the large flow passages in the annulus region, significant mounds of debris would not create a choke point preventing the recirculation fluid from transporting to the sump.

7. Reactor cavity basement and incore instrumentation tunnel and sump (elevation 1970'-6"): This area of evaluation encompasses the area under the reactor vessel in the reactor cavity as well as the incore instrumentation tunnel. Post-DBA water inventory flow to this area will come from the elevation 2001'-4" hatch north of the primary shield wall when the flood height exceeds 2001'-10" due to the protective 6-inch curb. In addition, flow to this area will also come from the permanent cavity seal ring access covers. This tunnel and area under the reactor cavity will retain water inventory during post-DBA recirculation mode operations. No potential choke points were identified in this area.

Response to 3.I.2. Summarize measures taken to mitigate potential choke points:

Administrative controls ensure the drains from the refueling cavity to lower containment are not obstructed during power operations.

Response to 3.I.3. Summarize the evaluation of water holdup at installed curbs and/or debris interceptors:

As discussed above, a 6-inch curb surrounds each containment recirculation sump pit, creating a 6-inch deep hold-up volume above the 2000'-0" floor elevation. Debris barriers installed in the Loop A and Loop D passageway entrances through the secondary shield wall do not impact water hold-up since Loop B and Loop C passageways allow debris laden fluid to flow into the containment building annulus area and to the recirculation sumps.

Response to 3.I.4. Describe how potential blockage of reactor cavity and refueling cavity drains has been evaluated, including likelihood of blockage and amount of expected holdup:

The refueling pool floor (elevation 2009'-9") contains two 10-inch diameter drains that are open during power operations. There are debris exclusion devices (trash-rack cages) installed during power operations over each of the 10-inch drains to prevent large pieces of debris from plugging the drains. The trash rack cages measure 33.5" x 33.5" x 15" with 5-inch openings. Figure 3.I-2 shows a trash rack cage installed over one of the 10-inch drains.

The 10-inch drains go straight through the refueling cavity floor slab and discharge into the open area below; thus, the drain pipes themselves would not become plugged with debris. Administrative controls ensure the drains from the refueling cavity to lower containment are not obstructed during power operations.

Figure 3.I-2: Refueling Pool Trash Rack Cage

3.m. 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. Provide the information requested in GL 04-02 Requested Information Item 2(d)(v) and 2(d)(vi) regarding blockage, plugging, and wear at restrictions and close tolerance locations in the ECCS and CSS downstream of the sump.

GL 2004-02 Requested Information Item 2(d)(v)

The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.

GL 2004-02 Requested Information Item 2(d)(vi)

Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

1. *If NRC-approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE)[1], briefly summarize the application of the methods. Indicate where the approved methods were not used or exceptions were taken, and summarize the evaluation of those areas.*
2. *Provide a summary and conclusions of downstream evaluations.*
3. *Provide a summary of design or operational changes made as a result of downstream evaluations.*

[1]The draft NRC SE for this document was issued to the applicant in November 2007.

Response to 3.m., Item 2(d)(v). The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flowpaths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the sump screen's mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.

The discussion that follows provides a basis for concluding that inadequate containment cooling will not occur due to debris blockage at flow restrictions in ECCS and CSS flow paths downstream of the sump strainer, such as HPSI throttle valves, pump bearings and seals and CS nozzles.

Analysis was performed using the methodology outlined in WCAP-16406-P (Reference [18]). No exceptions were taken to the WCAP-16406-P-A methodology. The analysis concluded that no modifications to components or instrumentation were necessary.

The following methodology was used:

a. The safety function of the containment heat removal systems and the ECCS that use the containment recirculation sump as the source for system cooling water was reviewed.
b. The systems for supporting the safety functions of the containment heat removal systems and the ECCS were identified.
c. The flow paths for each system used during recirculation mode were identified.
d. Flow diagrams, piping and instrumentation drawings, operating procedures, vendor manuals, etc., were reviewed to determine valve position(s) and the size of the flow passages in each component in the flow path.
e. The flow passageway for components in which there is a potential plugging concern was compared to the debris size.

Dimensions of particulates passing through a passive sump screen were determined as:

a. The width of deformable particulates that may pass through the sump screen is limited to the size of the flow passage hole in the sump screen, plus 10 percent.
b. The thickness of deformable particulates that may pass through the sump screen is limited to one-half the size of the flow passage hole.

c. The maximum length of deformable particulates that may pass through the flow passage hole in the sump screen is equal to two times the diameter of the flow passage hole.
d. The thickness and/or width and maximum length of non-deformable particulates that may pass through the sump screen is limited to the size of the flow passage hole in the sump screen.

The strainer area for Callaway is 6623 ft^2 (Reference [19]) assuming two operable trains to all allow the maximum about of debris to bypass and come into contact with downstream components and instrumentation. The debris load at Callaway includes fiber, coatings (unqualified and qualified), particulates, and chemicals.

Callaway has evaluated the downstream impact of sump debris on the performance of the ECCS and CSS following a LOCA. The analysis includes erosive wear, abrasion, and potential blockage of flow paths induced by debris ingested through the containment sump screen during the recirculation mode of the ECCS and CSS for an allotted mission time of 720 hours. Wear evaluations take into account the concentration of debris in the recirculation water as well as the size of the debris. This information is given in [20].

Table 3.m-1: Initial Mass Concentration for the Debris Load

Debris Type	Size	Mass Concentration, ppm
Penetrating Fiber (Includes Latent Fiber)	>100 μm	25
Qualified Coatings	10 μm	115
Depleting Coating Chips (large)	>400 μm	244
Non-Depleting Coatings (medium)	100 μm to 400 μm	16
Non-Depleting Coatings (small)	10 μm	224
Latent Particulate	10 μm	18
Chemical Debris	10 μm	64

Components evaluated for erosive wear include valves, spray nozzles and orifice plates in the recirculation flow path, the tube side of RHR heat exchangers, as well as, RHR, CS, CC and SI pumps for both suction and discharge sides. The analysis showed that for a constant debris concentration over the mission time of 30 days, erosive wear on these components is determined to be insufficient to affect the system performance. All pumps were evaluated for abrasive wear on suction and discharge sides, no pumps showed limited operation over the 30 day mission time.

Blockage analysis was conducted for components, based on maximum deformable debris size of 0.094” and non-deformable debris size of 0.047” (Reference [21]). Debris ingestion sizes are in relation to the containment sump strainers comprised of perforated plate with 0.045” ± 0.002” holes and assuming that deformable debris may bypass at two times the diameter of the hole. Based on the determined debris size each recirculation-critical flow channel, valve and nozzle at Callaway will not fail due to the recirculation of debris laden fluid according to acceptance criterial stated in WCAP-16406-P that when a flow passage is greater than 1 inch diameter and fluid velocity remains above 0.42 ft/s plugging will not occur.

The instrumentation tubing is also evaluated for potential blockage of the sensing lines. There are static flow instrument lines to various pressure or differential pressure transmitters connected to the system piping. The lines are nominally 0.75" in size. There is no flow from the main process line into these static instrument lines that would cause fiber or particulate matter to enter the lines. The instrumentation lines in the main process lines of the RHR system are all attached above the piping centerline, this placement eliminates the concern for debris settlement that could adversely affect the associated instruments.

Response to 3.m., Item 2(d)(vi). Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

The discussion that follows provides a basis for concluding that ECCS and CSS components are not susceptible to excessive plugging or excessive wear due to extended post-accident operation with debris-laden fluids.

Callaway pump bearings and seals were evaluated for plugging and determined to not be susceptible to deformable or non-deformable debris obstructing flow. The bearings, seals, and impellers were evaluated for wear and it was determined that for a 720 hour mission time, any wear imparted by debris laden fluid would be within acceptable limits. The evaluation was consistent with the methodology presented in WCAP-16406-P (Reference [18]).

Response to 3.m.1. If NRC-approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE)[1], briefly summarize the application of the methods. Indicate where the approved methods were not used or exceptions were taken, and summarize the evaluation of those areas:

The evaluations that provide the bases for conclusions presented in this section were developed using WCAP-16406-P-A, “Evaluation of Downstream Sump Debris Effects in Support of GSI-191” Revision 1 and the accompanying NRC SER

(Reference [18]). No exceptions were taken but there are items to note in the following categories;

1. Debris Size Distribution
   GSI-191 head loss evaluations commonly assume unqualified coatings failure is biased to a 10-µm particulate size, providing a higher fraction of debris that is transported to the strainer and a higher head loss response. However, this does not pose a challenging load for downstream effect analysis. Although generally used to describe degraded qualified coatings, the Alion-Comanche Peak failure fractions and size distribution, based on autoclave testing of degraded qualified coatings, is used to create a more reasonably challenging debris load for the Callaway wear evaluations. Furthermore, the fraction of failed fine coatings (49.51%) from the Alion-Comanche Peak distribution does not provide more specific size data for chips smaller than 1/8", which account for 12.4% of the 49.51% fines. Thus, 12.4% of 49.51%, or 6.14% of all failed coatings are assumed to be particulate in the range of 100 µm to 400 µm. Table 3.m-2 shows the failure fractions used in the Callaway downstream effects analysis.

   Table 3.m-2: Modified Alion-Comanche Peak Epoxy Failure Mass Fractions

Debris Classification	Total Debris Load Fractions
Fine (Assumes 12% of the 49.51% is 100 µm to 400 µm)	6.14%
Fine (Assumes other 88% of 49.51% is >400 µm)	43.36%
Flat small chips	5.02%
Flat small chips	4.41%
Flat large chips	20.54%
Curled chips	20.54%

2. Particulate Penetration
   Particulate penetration fraction of 24% was determined from a thin-bed test. Based on multiple industry strainer head loss tests, an estimate of 76% strainer capture of chemical debris is reasonable, and the actual value would be greater. Chemicals are assumed to form 10-µm particles, but are likely much smaller, and while small debris is not the highest contributor to wear, ultimately assuming more debris bypassing the strainer will cause greater wear on downstream components

3. Debris Depletion
   Callaway downstream wear evaluation takes into account debris depletion for pump evaluations. Fibrous debris, transportable RMI, particulate debris ≥100 µm

(except coatings), and coatings ≥400 μm are assumed to deplete over time. A debris depletion coefficient (λ) of 0.07 hr^{-1} is assumed corresponds to a depletion half-life of 10 hours in accordance with WCAP-16406-P methodology.

4. Unqualified Coatings.
   Due to the high transportability of small particulate, all unqualified coatings are assumed to fail as 10-μm spheres with 100% transportability to the sump strainer, effectively increasing the debris load that bypasses the strainer.

5. Fluid Velocity
   The Callaway downstream wear calculation models the fluid velocity to be equal to the velocity at time zero (t=0). This modeling assumption is based on the principle that velocity is inversely proportional to the flow area of the component that the fluid is moving through for a constant volumetric flow rate. As a component begins to wear, the velocity will decrease slightly and potentially decelerate the wear rate.

   The items above do not deviate from the WCAP-16046-P methodology and their implementation increases the conservatism built in to the Callaway downstream effects evaluation.

Response to 3.m.2. Provide a summary and conclusions of downstream evaluations:

The evaluations summarized in this section show that, using NRC-approved analysis methodologies and plant-specific equipment properties, inadequate containment cooling will not occur due to debris blockage at flow restrictions in ECCS and CSS flowpaths downstream of the sump strainer, such as HPSI throttle valves, pump bearings and seals and CS nozzles.

The RHR, CS, CC and SI pumps at Callaway were evaluated for downstream wear using maximum WCAP-16406-P methodology and were found not to be compromised by wear imparted by debris ingested in recirculating coolant during an accident. Table 3.m-3 shows the wear-to-design clearance factors for each category of pump.

Table 3.m-3: Wear-to-Design Clearance Factors for Pumps

Component	Clearance Factor (wear-to-design)	Performance Evaluation	Determination
RHR Pumps	1.2X	Hydraulic	Acceptable
CS Pumps	1.1X	Hydraulic	Acceptable
SI Pumps	>2.5X*	Mechanical Vibration	Acceptable
CC Pumps	>2.5X*	Mechanical Vibration	Acceptable

*Predicted post-wear stiffness is compared to that of the same pump considering symmetric 2.5X wear to both sides of the pump. If the combined asymmetric stiffness is greater than the combined symmetric stiffness, then pump performance is determined to be acceptable.

Valve performance acceptability maintains a design flow area increase of less than 3% at the completion of the mission time. Table 3.m-4 shows the Callaway valves evaluated and the associated flow increase percentage. No valves have an increase of greater than 3% of the original design flow area and thus will not be compromised over the 720 hour mission time.

Table 3.m-4: Valve Flow Increase Over 720 Hour Mission Time

Customer ID	ΔA/A, %
EMV0089	0.06
EMV0090	0.06
EMV0091	0.06
EMV0092	0.06
EMV0095	0.70
EMV0096	0.41
EMV0097	0.41
EMV0098	0.53
EMV0107	2.18
EMV0108	2.18
EMV0109	2.18
EMV0110	2.18

The acceptance criterion for RHR heat exchangers is that the minimum acceptable tube wall thickness is 0.0173 in. Wear evaluations determined that the eroded thickness of the tube wall would be 0.0489 in, which is considerably more robust than the minimum required thickness. The evaluation shows that the RHR heat exchanger will not be compromised due to debris laden fluid flow over the 720 hour mission time.

A list of orifices evaluated for Callaway is available in Table 3.m-5. According to WCAP-16406-P (Reference [18]) orifices must maintain a change in flow rate of less than the 3% over the 720 hour mission time. The results in Table 3.m-5 show that no orifices at Callaway are expected to fail because of wear imparted by debris ingested in a LOCA.

Table 3.m-5: Orifice Evaluation for Flow Increase over Mission Time

Location	ID	$\Delta Q/Q$ (%)
RHR accumulator	EJFO-2, 3 EPFO-3,4	0.119
RHR system	EJFO-5,6	0.0101
CS pump discharge	ENFE-5,11	0.013
RHR pump discharge	EJFE-610, 611	0.020
RHR cold leg injection	EJFE-618	0.012
RHR hot leg injection	EJFE-988	0.047
CC pump discharge	EMFE-917A, B	0.076
CC cold leg injection	EMFE-924, 925, 926, 927	1.930
SI pump discharge	EMFE-918, 922	0.048
SI cold leg injection	EMFE-980, 981, 982, 983	0.744
SI hot leg injection	EMFE-984, 985, 986, 987	0.691

The CSS sprays at Callaway are expected to have an increase in flow rate of 0.31%, over the course of the mission time. This result is well below the allowed 10% increase acceptance criteria given in WCAP-16406-P (Reference [18]) showing that spray nozzles at Callaway will not fail the mission time due to the recirculation of debris laden fluid.

The instrumentation tubing is also evaluated for potential blockage of the sensing lines. There are static flow instrument lines to various pressure or differential pressure transmitters connected to the system piping. The lines are nominally 0.75" in size. There is no flow from the main process line into these static instrument lines that would cause fiber or particulate matter to enter the lines. The instrumentation lines in the main process lines of the RHR system are all attached above the piping centerline, this placement eliminates the concern for debris settlement that could adversely affect the associated instruments.

Potential for blockage of the reactor vessel level instrumentation system (RVLIS) is not evaluated since Callaway has a Westinghouse designed RVLIS, and according to WCAP-16406-P-A (Reference [18]), the debris ingested through the sump strainers will not affect the reactor vessel water level measurements.

Response to 3.m.3. Provide a summary of design or operational changes made as a result of downstream evaluations:

At this time, no design or operational changes are being implemented to deal with downstream effects.

<u>Plugging of Close-Tolerance Subcomponents</u>:
Close-tolerance subcomponents in pumps, valves and other ECCS and CSS components were evaluated for potential plugging or excessive wear due to extended post-accident operation with debris-laden fluids. The evaluations were developed in accordance with WCAP-16406-P-A, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191" Revision 1 and the accompanying NRC SER (Reference [18]). No exceptions were taken to the WCAP-16406-P-A methodology.

The ECCS and CSS included in an evaluation of potential for plugging in downstream components are the CSS, chemical and volume control system (CVCS), high pressure coolant injection system (HPCIS), and the RHR (Reference [21]).

The potential for plugging of equipment in the ECCS and CSS recirculation flow paths (other than RHR pumps, centrifugal charging pumps, HPCIS pumps, and CSS Pumps) is analyzed in WES004-PR-01, Revision 2 (Reference [21]).

The following methodology was used in WES004-PR-01:

a. The safety function of the containment heat removal systems and the ECCS that use the containment recirculation sump as the source for system cooling water was reviewed.
b. The systems for supporting the safety functions of the containment heat removal systems and the ECCS were identified.
c. The flow paths for each system used during recirculation mode were identified.
d. Flow diagrams, piping and instrumentation drawings, operating procedures, vendor manuals, etc., were reviewed to determine valve position(s) and the size of the flow passages in each component in the flow path.

e. The flow passageway for components in which there is a potential plugging concern was compared to the debris size.

Dimensions of particulates passing through a passive sump screen were determined as:

a. The width of deformable particulates that may pass through the sump screen is limited to the size of the flow passage hole in the sump screen, plus 10 percent.
b. The thickness of deformable particulates that may pass through the sump screen is limited to one-half the size of the flow passage hole.
c. The maximum length of deformable particulates that may pass through the flow passage hole in the sump screen is equal to two times the diameter of the flow passage hole.
d. The thickness and/or width and maximum length of non-deformable particulates that may pass through the sump screen is limited to the size of the flow passage hole in the sump screen.

Accordingly, the maximum debris size used in the evaluation was 0.094 inch for deformable debris and 0.047 inch for non-deformable debris.

With regard to flow area evaluation for plugging of check valves, section 7.3.3.3 of WCAP-16406-P-A (Reference [18]) states that "in accordance with Westinghouse WCAP-11534 (Reference [22]), a minimum velocity of 0.42 ft/sec is needed to flush the debris in a system. If the minimum velocity is met, the valve will pass the debris, provided the valves are larger than 1 inch. In the event the minimum velocity is not met or the valve is 1 inch or less, vendor input is required. For lift check valves of sizes 1-1/2 inch or greater, the clearance dimension between the plug and the seat is generally greater than 11/32 inch." These criteria were used to assess plugging of check valves.

The results of the assessment performed in WES004-PR-01 (Reference [21]) pertain to four systems that are critical to recirculation. The RHR, volume control, HPCIS and CSS were analyzed and it was found that all valves, piping, flow instruments, heat exchangers and spray nozzles that are involved in recirculation meet the same plugging assessment criteria. Based on deformable particulate size of 0.094 inch and non-deformable particulate size of 0.047 inch, each recirculation-critical flow channel, valve and nozzle was found to be greater than 1 inch diameter and fluid velocity remains above 0.42 ft/s in each case. These results confirm that each component involved in recirculation can accommodate sump bypass particles without plugging.

<u>Wear and Abrasion</u>:
Assessment of erosive wear and abrasion of equipment wear of ECCS and CSS equipment is based on results of analysis in CN-CSA-05-20, Revision 2 (Reference [23]).

The mass of debris in recirculating fluid that passes through the sump is characterized in terms of concentration in parts per million (ppm). For downstream effects, the total initial debris comprised of the individual debris concentrations is defined as the ratio of the solid mass of the debris in the pumped fluid to the total mass of water that is being recirculated by the ECCS and CSS. The individual mass concentrations, computed in CN-CSA-05-49, Revision 2 (Reference [24]), rounded up to the nearest whole number for reporting purposes are displayed in Table 3.m.6.

Table 3.m-6: Mass Concentrations

Debris Type	Concentration (ppm)
Fibrous	33
Particulate	7
Coatings	248
Chemical	8
TOTAL	296

Based on the results in CN-CSA-05-20 (Reference [23]), with no consideration of debris depletion, the erosive wear on heat exchangers, orifices, and spray nozzles due to fluid with 296 ppm debris concentration over a mission time of 30 days is insufficient to affect the system performance.

<u>Pump Performance</u>:
For pumps, three aspects of the effect of debris ingestion through the sump strainers were addressed: (1) hydraulic performance, (2) mechanical shaft seal assembly performance, and (3) mechanical performance (vibration).

Based on the analysis documented in CN-CSA-05-20 (Reference [23]), the hydraulic and mechanical performance of ECCS and CSS pump were determined to be unaffected by recirculating sump debris.

Mechanical shaft seal assembly performance evaluation resulted in two action items: (1) evaluation of cyclone separators and the impact on their function, and (2) the evaluation of the pumps' carbon/graphite backup seal bushings due to the plant-specific debris mix.

Analysis documented in LTR-SEE-I-08-138 (Reference [25]) showed that the cyclone separators will not become blocked by recirculation debris. Analysis documented in CN-SEE-I-08-67 (Reference [26]) demonstrated that the primary seals are not expected to fail as a function of debris.

Callaway centrifugal charging and safety injection pumps are multi-stage and had to be evaluated for mechanical vibration. Based on the evaluation documented in CN-CSA-05-20 (Reference [23]), using the methodology in Appendix R of WCAP-16406-P-A (Reference [18]), it is shown for both the centrifugal charging and safety injection pumps that the stiffness provided by the worn suction side wear ring is larger than the combined stiffness provided by the suction and discharge wear rings at a symmetric clearance of two times the design clearance. On that basis, the centrifugal charging and safety injection pumps pass the vibration evaluation.

<u>Heat Exchanger Wear</u>:
Tube failure for heat exchangers will occur when the resultant wall thickness after erosion is less than the required wall thickness to retain internal and external pressures.

The analysis in CN-CSA-05-20 (Reference [23]) shows that without consideration of debris depletion, the actual tube wall thickness minus the eroded wall thickness is greater than the wall thickness required to retain pressure. Therefore, failure of the tube wall will not occur. In addition, because erosion of the tube wall due to fluid-borne debris is less than 1% of the actual wall thickness, any pre-existing wear of the heat exchanger tube wall with normal (debris-free) fluid is considered negligible.

<u>Orifice Wear</u>:
To evaluate failure of orifices, the increase in the orifice inner diameter due to erosive wear must be proven to not affect the system performance. Based on section 8.4 of WCAP-16406-P-A (Reference [18]), an insignificant amount of wear occurs when the system flow through the orifice is changed by less than 3%, where 2% is the standard orifice tolerance and 1% is repeatability.

The analysis in CN-CSA-05-20 (Reference [23]) shows that without consideration of debris depletion the change in the system flow from erosive wear through the orifices is less than 3%. Therefore erosive wear will not affect the system performance.

<u>Spray Nozzle Wear</u>:
For spray nozzles, failure due to erosive wear is considered to occur when the flow from the nozzle increases by 10% due to the increase in the nozzle inner diameter.

The analysis in CN-CSA-05-20 (Reference [23]) shows that without consideration of debris depletion, the change in spray nozzle flow is less than 1%, which is under the 10% criterion. Therefore erosive wear will not affect the spray nozzle performance.

<u>Instrumentation Blockage</u>:
Potential for blockage of the RVLIS is not evaluated since Callaway has a Westinghouse designed RVLIS, and according to WCAP-16406-P-A (Reference [18]), the debris ingested through the sump strainers will not affect the reactor vessel water level measurements.

3.n. 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 core cooling.

1. *Show that the in-vessel effects evaluation is consistent with, or bounded by, the industry generic guidance (WCAP-16793)[2], as modified by NRC staff comments on that document. Briefly summarize the application of the methods. Indicate where the WCAP methods were not used or exceptions were taken, and summarize the evaluation of those areas.*

   [2]Because this document is still under NRC review, licensees should be aware of any NRC RAIs on it. The draft NRC SE for WCAP-16793 is expected to be issued in December 2007. After resolution of any open items from the staff's evaluation of this document, the staff will determine whether additional information is needed from licensees. Licensees should not delay their GL responses pending this information.

Callaway assessed downstream in-vessel debris effects using WCAP-17788 methodology [27], debris penetration results obtained from 2016 strainer testing that yielded a 4-parameter correlation for fiber penetration and shedding as a function of strainer load, and pool/vessel recirculation equations implemented for STP risk-informed pilot evaluations. In-vessel analyses were performed assuming 300 lbm of fiber impinging on two operating ECCS strainers, allowing significantly more fiber to pass through the thinner debris beds. Previous WCAP testing determined that in-vessel chemical products will not form prior to 6 hours.

There are 193 fuel assemblies in the Callaway reactor core, which has a Westinghouse reactor design with an upflow barrel/baffle region. The reactor core may contain any combination of Westinghouse fuel assemblies, and a limited number lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions as provided in Technical Specification 4.2.1. Switchover to hot leg injection occurs at approximately 13 hours after nearly all fiber debris is deposited on the strainer or in the fuel, so the WCAP analysis is not sensitive to this parameter.

WCAP-17788 analysis results pass all performance criteria for both hot and cold leg breaks. For cold-leg breaks, fiber inventory at the core inlet and in the core volume are determined to be 5.46 g/FA (i.e., below the WCAP-17788-P, Rev. 0, Volume 1, Section 9.2.1 in-core limit). Based on the results of this analysis, fiber accumulation in the reactor vessel would not preclude adequate core cooling in an accident scenario that generates and transports 300 lbm of fibrous debris with both ECCS strainers running.

<u>Background</u>

Ameren Missouri addresses GL 2004-02 questions regarding in-vessel debris accumulation and blockage by performing analyses (References [28], [29]) consistent with WCAP-17788-P (Reference [30]). The only material differences compared to the WCAP-17788-P formalism are that Callaway pool circulation equations include a time-dependent strainer filtration function calibrated to test data rather than applying a constant filtration efficiency, and the Callaway strainer filtration function allows fiber shedding to occur from an established debris bed, even when filtration efficiency nears 100%. The Callaway analysis includes calculation of total fiber accumulating in the core and total fiber accumulating at fuel channel inlets for the tested 300-lbm fiber debris load (Reference [19]). All results from the WCAP-17788-P calculation are found to be favorable for the Westinghouse fuel type used at Callaway. Although WCAP-17788-P has not been endorsed by the Nuclear Regulatory Commission (NRC) as official guidance, it does provide an industry benchmark against which to compare plant-specific arguments needed to satisfy GL 2004-02.

The important finding of WCAP-17788-P is that core cooling can be maintained with some tolerable amount of fiber accumulation in every fuel assembly, because the sum of impeded direct flow and alternate-path flow is sufficient to avoid maximum fuel-temperature limits, under some conditions. Core cooling can be maintained with alternate-path flow provided that maximum allowed fuel channel blockage does not occur before post-LOCA time t_{block} that is tied to a conservative decay heat history and depends on core design and fuel type. This conclusion is based on: 1) fuel channel testing performed to determine flow-loss coefficients under a range of fiber loads for several fuel types, and 2) thermal hydraulic calculations performed to verify acceptable fuel temperatures given a maximum tolerable fiber load in every fuel channel. The WCAP-17788-P study assumes a nominal sump switchover (SSO) time of 20 minutes when Emergency Core Cooling System (ECCS) injection is drawn from the sump rather than from the Refueling Water Storage Tank (RWST). Sump switchover time determines the post-LOCA time when debris begins to arrive at the strainer and in the fuel, and the decay heat load at the time of maximum allowed blockage.

The minimum SSO for Callaway is approximately 12 minutes (11.87 min) for a Large-Break Loss of Coolant Accident (LBLOCA) (Reference [31]), and the corresponding decay heat is higher at 12 minutes than the 20-minute decay heat used for WCAP-17788-P thermal hydraulic verification of adequate cooling. Several arguments presented here support adequacy of the Callaway in-vessel blockage analysis with a 12-minute SSO time, including a comparison of decay-heat reference points between Callaway and the WCAP-17788-P analysis, and an examination of core-fiber accumulation histories. A Callaway SSO time of approximately 15 minutes (14.82 min) occurs under the FSAR licensing basis Maximum Safeguards configuration where only one containment spray pump is assumed to operate (Reference [32]), and this configuration leads to higher, but still acceptable, in-vessel fiber loads.

It is recognized that downstream fiber diversion through spray systems reduces the amount of fiber reaching the vessel (WCAP-17788-P), so in-vessel blockage analyses are reported here for the Maximum Safeguards configuration where one spray pump is unavailable and both ECCS trains function normally. Although dual-train spray actuation is the most likely plant LOCA response, loss of one spray pump is consistent with the Callaway licensing basis that requires operation of at least one spray train to meet radiological dose and Environmental Qualification (EQ) concerns. By Callaway Emergency-Operating Procedures (EOPs), at least one spray continues to operate until a relatively low differential containment pressure of 4.5 psi is reached, at which point, operators have the discretion to terminate spray. In many simulations, even two-train spray operation requires multiple days to achieve depressurization. Depressurization time is longer for single-train spray operation. Therefore, the Maximum Safeguards configuration provides the most conservative flow condition with respect to in-vessel effects that is consistent with the licensing basis and with existing EOPs. Conversely, full dual-train spray and dual-train ECCS was assumed and tested for the purpose of recirculation strainer performance characterization.

Decay-Heat Comparison

WCAP-17788-P Volume 1 Section 5.3.3.5 "Conservative Assumptions" documents the decay heat standard used in the WCAP analyses. Decay heat is modeled similar to the requirements in 10 CFR Part 50, Appendix K. The analyses use the 1971 American Nuclear Society (ANS) Proposed Standard, “Decay Energy Release Rates Following Shutdown of Uranium Fueled Thermal Reactors” with a 1.2 multiplier applied for conservatism.

For the reference plant modeled in the WCAP analysis, decay heat at the assumed SSO time of 20 minutes is 87.4 MW_{th} (including the 20% conservatism). For Callaway's conservatively calculated minimum SSO time of 11.87 minutes, decay heat is approximately 10% higher at 96.7 MW_{th} using the same decay methodology described in the WCAP (see Figure 3.n-1).

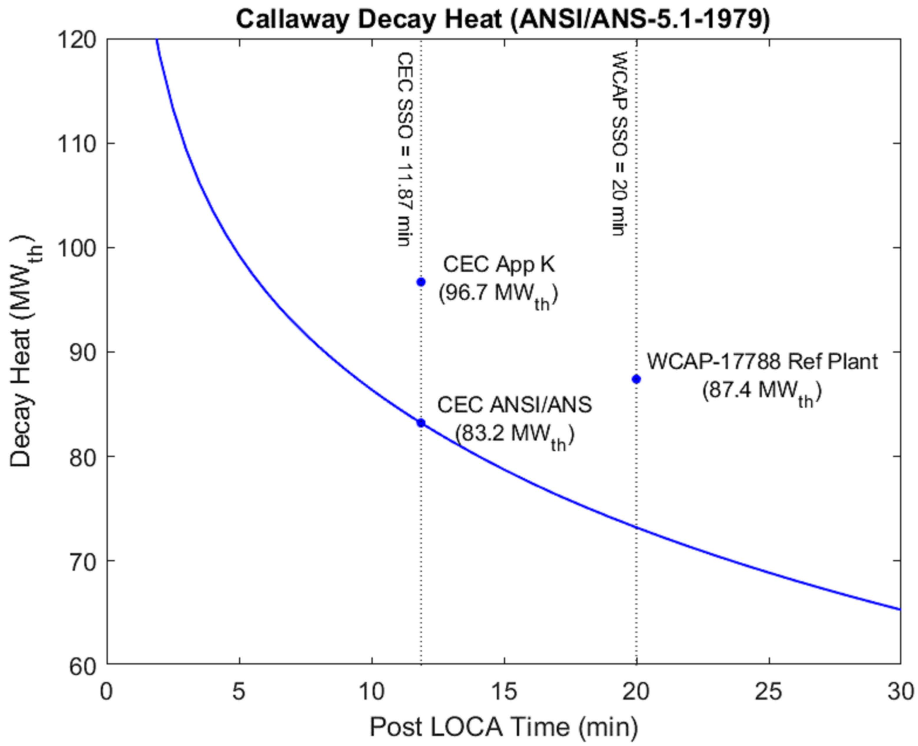


Figure 3.n-1. Callaway and WCAP-17788 Decay Heat Comparison.

The 1971 ANSI methodology with 20% increase factor introduces a large conservatism in the calculated decay heat. By comparison, the Callaway FSAR references ANSI/ANS-5.1-1979, "American National Standard for Decay Heat Power in Light Water Reactors", August 1979 for multiple Design Basis Accidents including Steam Generator Tube Rupture and Main Feedline Break. The 1979 decay heat standard is accepted as a conservative methodology and results in a calculated decay heat of approximately 83.2 MW_{th} at the 11.87-minute SSO time, which is approximately 14% lower than calculated for Callaway using the Appendix K / WCAP-17788 methodology (96.7 MW_{th}) and 5% lower than the decay heat modeled for the reference plant (87.4 MW_{th}) at the WCAP assumed 20-minute SSO time.

For a LBLOCA at Callaway, sump recirculation and fiber accumulation can begin approximately 8 minutes sooner than assumed in the WCAP-17788-P analysis. Given that the minimum Callaway pool turn over time is approximately 20 minutes, assuming minimum water volume and dual train ECCS injection flow, the 8 minute difference means that less than 1/2 of the pool volume has passed through the strainer while decay heat is dropping. If the higher Callaway Appendix K decay heat point in Figure 3.n-1 is chosen as the starting point, 8 minutes of decay reduce the heat load to be approximately equal to the WCAP-17788-P 20-min SSO heat load (a reduction of approximately 10%). This observation assumes a similar rate of decay between the

1979 ANSI/ANS decay heat methodology (blue history in Figure 3.n-1) and the 1971 ANSI decay heat methodology with added conservatism (curve not shown in Figure 3.n-1).

To summarize, WCAP-17788-P introduces a large conservatism by using the 1971 ANS decay heat standard with a 1.2 multiplier. Comparing the reference plant decay heat at the assumed 20-minute SSO time to the Callaway-specific value calculated using the ANSI/ANS-5.1-1979 standard at an 11.87-minute SSO time shows that the decay heat modeled in the WCAP-17788-P analyses remains bounding for the earlier Callaway SSO time and for all recirculation times thereafter.

Core-Fiber Accumulation Histories

Examination of core fiber histories calculated for dual train ECCS and dual train CS under the assumption of maximum flow split to alternate flow paths (Figure 3.n-2) shows that after 8 minutes of Callaway sump recirculation, the amount of fiber present at the core inlet (black dot) is approximately 91% of its final equilibrium maximum, and the equilibrium maximum never approaches more than 63% of the WCAP-17788-P recommended limit of 50.6 g/FA*. (After 8 minutes of recirculation, the core inlet inventory is only 57% of the recommended limit). Note that the time t_{block} represents the time after which total fuel-inlet blockage can be tolerated without incurring fuel damage, concurrent with the WCAP 20-minute decay heat history. Similarly, the total reactor vessel fiber inventory (upper bold red history in Figure 3.n-2) never reaches the WCAP-17788-P (Volume 1, Section 6.5.5.10.c) recommended limit. Total fiber accumulating in the heated core region through alternate flow paths (dashed history) is higher than the core-inlet fiber total inventory, indicating that sufficient resistance builds on the fuel inlets to divert flow to alternate flow paths. Fiber histories presented in Figure 3.n-2 are calculated assuming minimum flow, two-train core spray diversion after a post-SSO delay of 7.75 min to achieve full realignment. All fiber arriving in the core is retained permanently.

A similar examination of core fiber histories calculated for dual train ECCS and dual train CS under the assumption of minimum flow split to alternate flow paths (**Figure 3.n-3**) shows that after 8 minutes of Callaway sump recirculation, the amount of fiber present at the core inlet (black dot) is approximately 78% of its final equilibrium maximum, and the equilibrium maximum never approaches more than 89% of the WCAP-17788-P recommended limit of 50.6 g/FA*. (After 8 minutes of recirculation, the core inlet inventory is only 69% of the recommended limit). The change in assumed AFP flow split does not change total fiber inventory accumulating in the reactor vessel, but total fiber accumulating in the heated core region through alternate flow paths (dashed history) is now lower than the core-inlet fiber inventory because of the applied WCAP-17788-P correlation for minimum AFP flow split. All other parameters remain the same as for Figure 3.n-2.

* As shown in WCAP-17788-NP, Volume 4, Rev. 1, December 2019, Figure RAI-4.7-20, this value is non-proprietary.

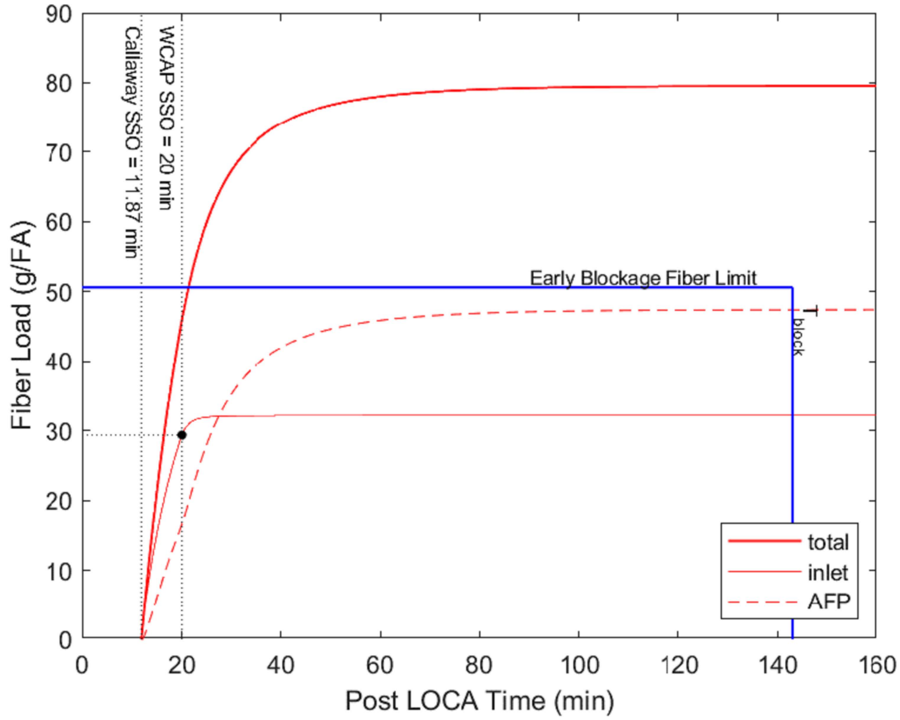


Figure 3.n-2. Callaway LBLOCA fiber histories for 11.87-min SSO time and dual-train operation with maximum AFP flow split.

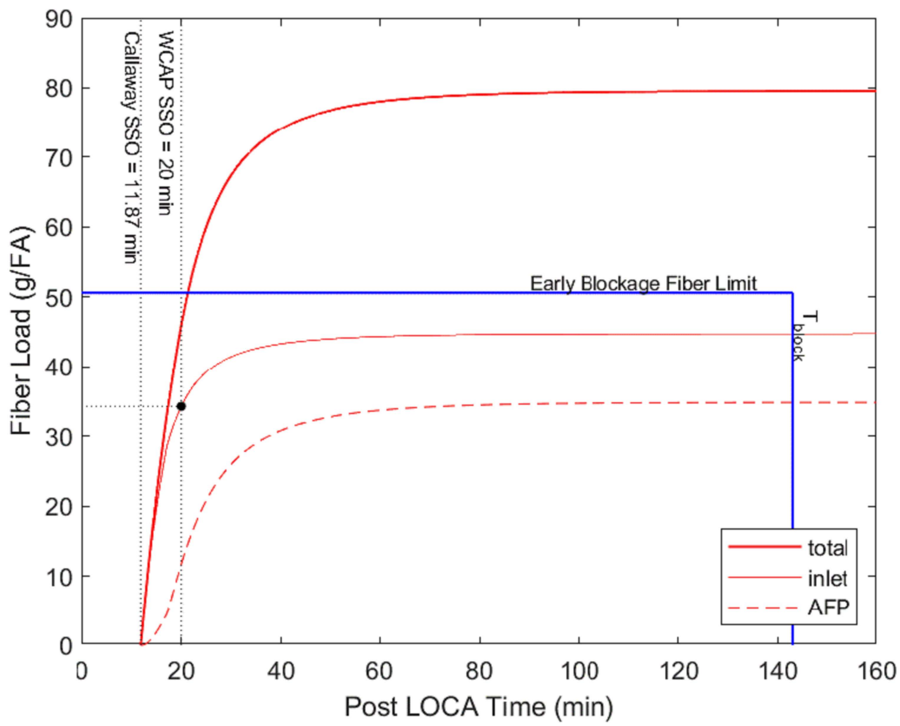


Figure 3.n-3. Callaway LBLOCA fiber histories for 11.87-min SSO time and dual-train operation with minimum AFP flow split.

Under the Callaway Maximum Safeguards configuration, one containment spray pump is assumed to fail, delaying SSO to 14.82 minutes and allowing more fiber transport directly to the reactor vessel. Figure 3.n-4 illustrates core fiber histories for the Maximum Safeguards configuration under the assumption of maximum AFP flow split. Maximum fuel inlet fiber is the same as in **Figure 3.n-2**, but AFP fiber increases significantly, raising the total core inventory by 10 g/FA. Again, all WCAP-17788-P reactor vessel fiber limits are satisfied. Figure 3.n-5 illustrates core fiber accumulation for under the assumption of minimum AFP flow split. Fuel inlet fiber is higher than shown in Figure 3.n-4, but does not exceed the recommended early blockage limit.

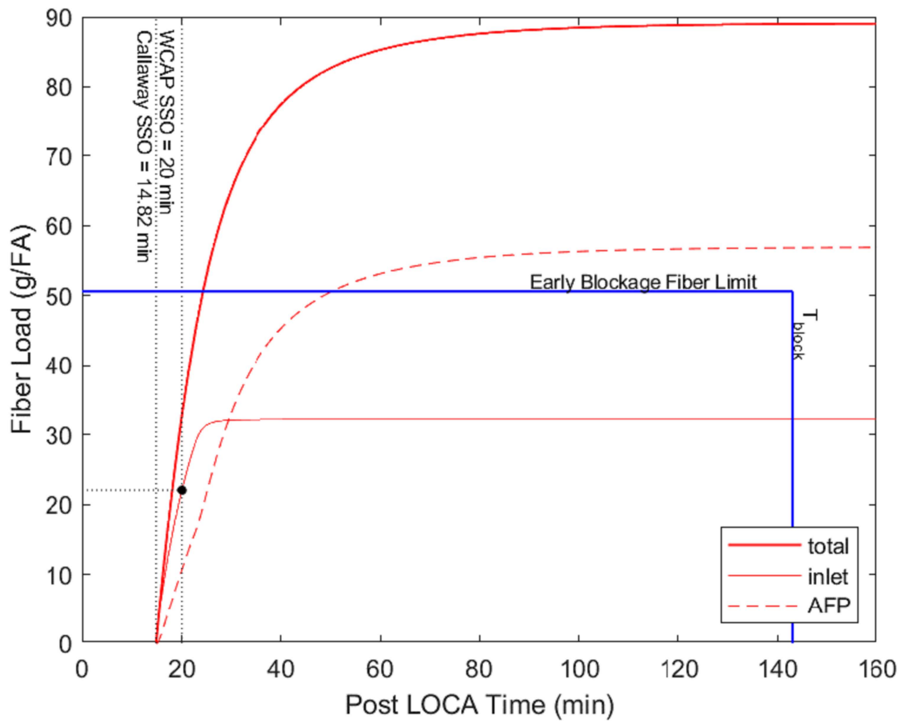


Figure 3.n-4. Callaway LBLOCA fiber histories for 14.82-min SSO and Maximum Safeguards operation (one CS pump failed) with maximum AFP flow split.

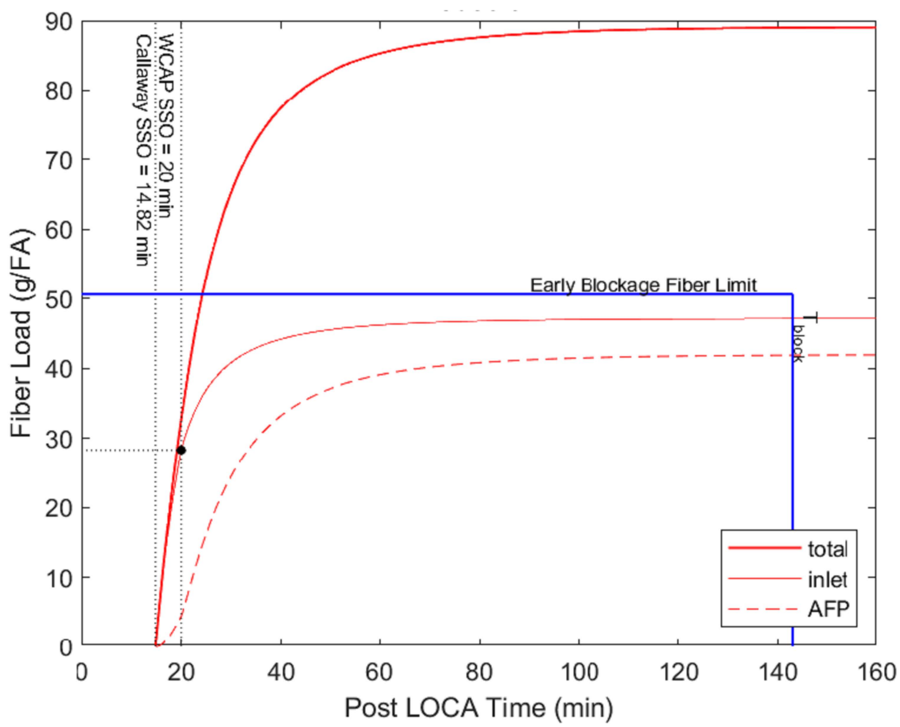


Figure 3.n-5. Callaway LBLOCA fiber histories for 14.82-min SSO and Maximum Safeguards operation (one CS pump failed) with minimum AFP flow split

In summary, although Callaway begins sump recirculation approximately 8 minutes earlier than assumed in the WCAP-17788-P analysis, the Callaway in-vessel fiber analysis remains valid for the following reasons:

1) The WCAP 20-minute heat load bounds the Callaway heat load at the earlier 11.87-minute SSO time that is used for FSAR accident analyses, and therefore, bounds decay heat at all later recirculation times.
2) Callaway App-K heat loads at the earlier 11.87-minute SSO time decay by 10% within 8 minutes to be approximately equal to the WCAP 20-minute heat load, while 91% of the final equilibrium fuel-channel fiber inventory has accumulated (equals only 63% of the recommended limit).
3) Total fuel-channel fiber inventory never reaches more than 90% of the WCAP-17788-P recommended maximum limit (Maximum Safeguards configuration), leaving adequate flow capacity to compensate for 8 minutes of higher heat load assumed under the WCAP-17788-P decay heat methodology.
4) These conclusions hold for two-train (all pumps running) and Maximum Safeguards (one CS failed) plant-response configurations. While the Maximum Safeguards configuration indicates higher reactor vessel fiber loads, expected dual train response provides defense in depth assurance of adequate cooling.

3.o. Chemical Effects[3]

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling.

1. *Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.*
2. *Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession Nos. ML072600425, ML072600372).*

[3]The NRC staff expects to issue a draft SE on WCAP-16530, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," in November 2007.

The information in this section revises information previously provided by Ameren Missouri to GL 2004-02, section 3.o. (Reference [2]). Evaluation of the effects of chemical precipitate on head loss relies on completion of the actions associated with vendor testing completed in 2016 meant to support assumptions and corresponding conclusions contained in this GL 2004-02 response.

Response to 3.o.1. Provide a summary of evaluation results that show that chemical precipitates formed in the post-LOCA containment environment, either by themselves or combined with debris, do not deposit at the sump screen to the extent that an unacceptable head loss results, or deposit downstream of the sump screen to the extent that long-term core cooling is unacceptably impeded.

Debris and other containment sources which could contribute to the formation of chemical precipitates in the sump pool were evaluated using the WCAP-16530-NP Spreadsheet.

Strainer head loss test was conducted in 2016. The head loss testing showed acceptable head loss for the conditions tested.

Response to 3.o.2. Content guidance for chemical effects is provided in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession Nos. ML072600425, ML072600372).

3.o.2.1 *Sufficient 'Clean' Strainer Area:* Those licensees performing a simplified chemical effects analysis should justify the use of this simplified approach by providing the amount of debris determined to reach the strainer, the amount of bare strainer area and how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed.

Ameren Missouri is not crediting a simplified chemical effects testing. The chemical effects evaluation process flow chart provided in the NRC guidance document has been modified, as shown in Figure 3.o-1, to highlight the process approach taken for testing and evaluation.

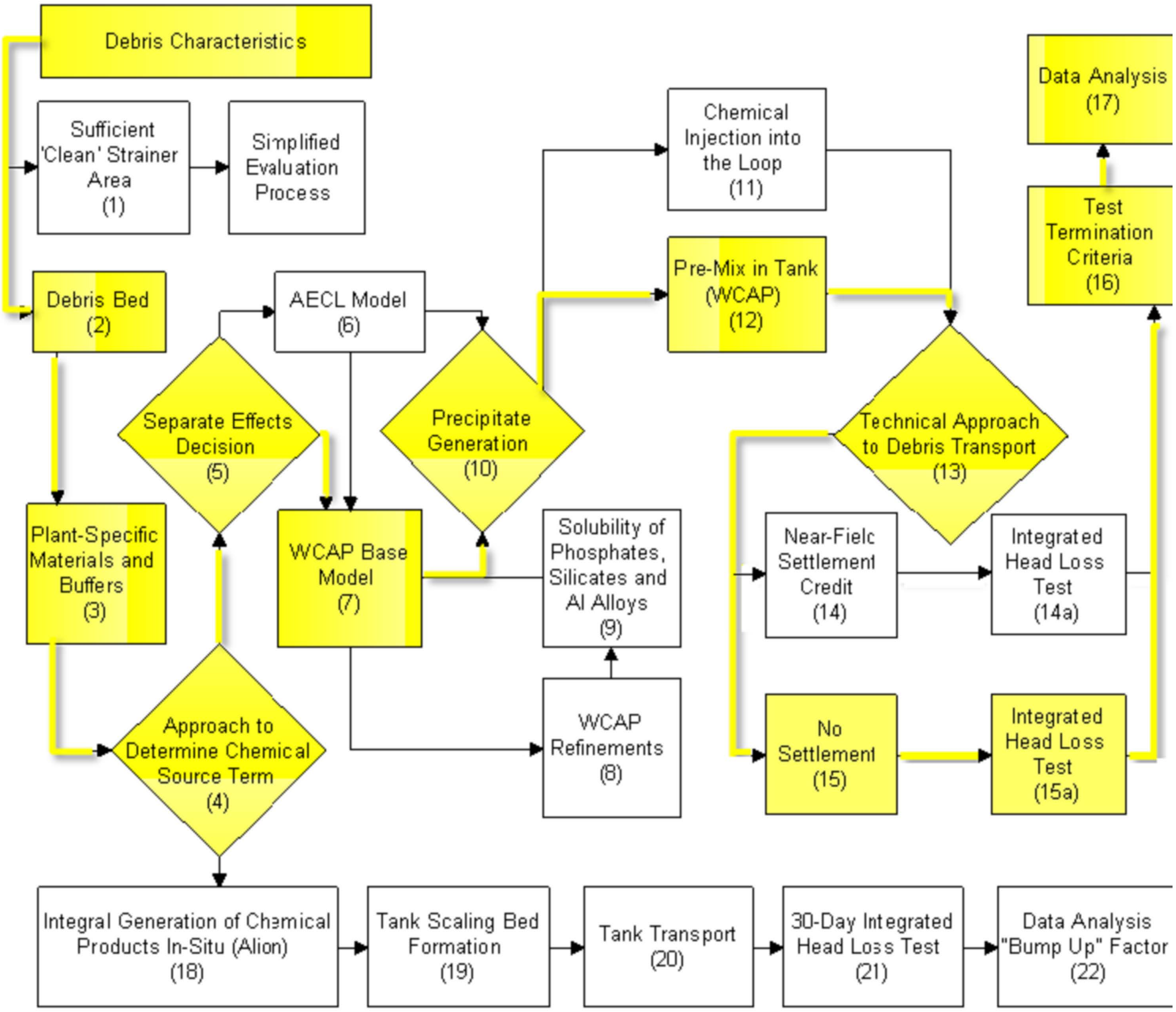


Figure 3.o-1: Chemical Effects Evaluation Process Flow Chart

3.o.2.2 *Debris Bed Formation:* Licensees should discuss why the debris from the break location selected for plant-specific head loss testing with chemical precipitate yields the maximum head loss. For example, plant X has break location 1 that would produce maximum head loss without consideration of chemical effects. However, break location 2, with chemical effects considered, produces greater head loss than break location 1. Therefore, the debris for head loss testing with chemical effects was based on break location 2.

The maximum chemical and particulate loads were paired with the RoverD fiber threshold. Therefore, the debris bed with most amount of chemical and particulates was tested, which is expected to yield maximum head losses.

3.o.2.*3 Plant-Specific Materials and Buffers:* Licensees should provide their assumptions (and basis for the assumptions) used to determine chemical effects loading: pH range, temperature profile, duration of containment spray, and materials expected to contribute to chemical effects.

The following major assumptions were made in calculating the post-accident chemical effects analysis for Callaway.

- The initial sump pH was assumed to be pH (4.6) from the maximum Boron concentration in pool (2500ppm).
- The initial spray pH (4.8) was assumed to be the pH of the spray additive solution.
- The spray pH values from the time of recirculation were assumed to equal the sump pH values.
- The temperature profile implemented was the LOCA DBA temperature profile.
- The sprays are on for 30-days.
- Undamaged insulation is covered by stainless steel jacketing that minimizes insulation exposure to CS. Jackets act as a protective barrier for underlying insulation and minimizes internal wetting of the insulation. Even if the interior is dampened, the solution likely remains inside the jacket secluded from the containment pool. Therefore, undamaged, jacketed insulation is not included in the sprayed insulation inventory for WCAP-16530 predictions.
- The "intact blanket" portion of the NUKON® debris is not considered as a reactant source, and is not included in the inventory for WCAP-16530 predictions.

The Callaway CSS uses TSP as a buffer solution. The TSP is mixed by the containment sump recirculation pool water prior to being sprayed into the containment building.

Table 3.o-1: Input for Chemical Effects Evaluation

Parameter	Value
Aluminum (submerged) surface area	458 ft^2
Aluminum (submerged) mass	1,145 lbm
Aluminum (unsubmerged) surface area	273 ft^2(2)
Aluminum (unsubmerged) mass	851 lbm
NUKON®	410 ft^3
NUKON® density	2.4 lbm/ft^3
Concrete	2,623.5 ft^2
Maximum recirculation water volume	63,656.7 ft^3(3)
Buffering agent	TSP
Sump temperature, minimum	170.9 °F
Sump temperature, maximum	262.2 °F
Sump pH post-LOCA, min / max	4.6 / 7.6
Spray pH post-LOCA, min / max	4.8 / 7.6
Spray duration	30 days

3.o.2.4 *Approach to Determine Chemical Source Term (Decision Point):* Licensees should identify the vendor who performed plant-specific chemical effects testing.

The strainer performance testing was conducted at the Alden facility in Holden, Massachusetts and performed by ALDEN personnel.

3.o.2.5 *Separate Effects Decision (Decision Point):* State which method of addressing plant-specific chemical effects is used.

The methods of WCAP-16530 were used to access the plant-specific chemical effects precipitate loading and testing chemical precipitates were produced using the methods in WCAP-16530.

3.o.2.6 Since the NRC USNRC is not currently aware of the testing approach, the NRC USNRC expects licensees using it to provide a detailed discussion of the chemical effects evaluation process along with head loss test results.

Ameren Missouri did not use an AECL Model.

3.o.2.7 *AECL Model:* Licensees should provide the chemical identities and amounts of predicted plant-specific precipitates.

Ameren Missouri did not use an AECL Model.

3.o.2.8 *WCAP Base Model:* For licensees proceeding from block 7 to diamond 10 in the Figure 1 flow chart [in Enclosure 3 to a letter from the NRC to NEI dated September 27, 2007 (ADAMS Accession No. ML0726007425)], justify any deviations from the WCAP base model spreadsheet (i.e., any plant-specific refinements) and describe how any exceptions to the base model spreadsheet affected the amount of chemical precipitate predicted.

Ameren Missouri did not take credit for any exceptions to the base model of WCAP-16530 spreadsheet.

3.o.2.9 *WCAP Base Model:* List the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.

The WCAP-16530-NP base model spreadsheet was used. The results of the analysis are shown in Table 3.o-2 below.

Table 3.o-2: Predicted Chemical Precipitate Formation for Ameren Missouri Baseline Methodology

Type of precipitate	Pounds (lbm)
AlOOH	0
$NaAlSi_3O_8$	474
$Ca_3(PO_4)_2$	55

Calcium phosphate precipitate was a chemical precipitate shown to be formed using the chemical effects spreadsheet. Calcium phosphate was used in the testing for the quantities of calcium phosphate required.

Although sodium aluminum silicate ($NaAlSi_3O_8$) was a chemical precipitate shown to be formed using the chemical effects spreadsheet, AlOOH was used as a surrogate. This substitution was used because the production of $NaAlSi_3O_8$ is considered hazardous. The justification is from section 7.3.2 of WCAP-16530-NP, which stated that the characteristics of $NaAlSi_3O_8$ are sufficiently similar to AlOOH, thus AlOOH may be used in lieu of $NaAlSi_3O_8$.

3.o.2.10 *WCAP Refinements:* State whether refinements to WCAP-16530-NP were utilized in the chemical effects analysis.

No refinements to WCAP-16530 were utilized in the chemical effects analysis.

3.o.2.11 *Solubility of Phosphates, Silicates and Al Alloys:* Licensees should clearly identify any refinements (plant-specific inputs) to the base WCAP-16530 model and justify why the plant-specific refinement is valid.

No plant-specific refinements were utilized.

3.o.2.12 *Solubility of Phosphates, Silicates and Al Alloys:* For crediting inhibition of aluminum that is not submerged, licensees should provide the substantiation for the following: (1) the threshold concentration of silica or phosphate needed to passivate aluminum, (2) the time needed to reach a phosphate or silicate level in the pool that would result in aluminum passivation, and (3) the amount of containment spray time (following the achieved threshold of chemicals) before aluminum that is sprayed is assumed to be passivated.

Inhibition or passivation of aluminum was not used in determining the aluminum corrosion and the resultant chemical precipitates.

3.o.2.13 *Solubility of Phosphates, Silicates and Al Alloys:* For any attempts to credit solubility (including performing integrated testing), licensees should provide the technical basis that supports extrapolating solubility test data to plant-specific conditions. In addition, licensees should indicate why the overall chemical effects evaluation remains conservative when crediting solubility given that small amount of chemical precipitate can produce significant increases in head loss.

No reduction of chemical precipitate was achieved by crediting solubility.

3.o.2.14 *Solubility of Phosphates, Silicates and Al Alloys:* Licensees should list the type (e.g., AlOOH) and amount of predicted plant-specific precipitates.

The amount and type of precipitate predicted is discussed in response 3.o.2.9.

3.o.2.15 ***Precipitate Generation (Decision Point):*** **State whether precipitates are formed by chemical injection into a flowing test loop or whether the precipitates are formed in a separate mixing tank.**

Precipitates are formed in a separate mixing tank.

3.o.2.16 ***Chemical Injection into the Loop:*** **Licensees should provide the one-hour settled volume (e.g., 80 ml of 100 ml solution remained cloudy) for precipitate prepared with the same sequence as with the plant-specific, in-situ chemical injection.**

Precipitates were not formed by injection into the test loop.

3.o.2.17 ***Chemical Injection into the Loop:*** **For plant-specific testing, the licensee should provide the amount of injected chemicals (e.g., aluminum), the percentage that precipitates, and the percentage that remains dissolved during testing.**

Precipitates were not formed by injection into the test loop.

3.o.2.18 ***Chemical Injection into the Loop*****: Licensees should indicate the amount of precipitate that was added to the test for the head loss of record (i.e., 100%, 140%).**

Precipitates were not formed by injection into the test loop.

3.o.2.19 ***Pre-Mix in Tank:*** **Licensees should discuss any exceptions taken to the procedure recommended for surrogate precipitate formation in WCAP-16530.**

No exceptions to the procedure in WCAP-16530 were taken for the surrogate precipitate formation.

3.o.2.20 ***Technical Approach to Debris Transport (Decision Point):*** **State whether near field settlement is credited or not.**

Ameren Missouri chemical effects head loss testing did not credit for near field settling.

3.o.2.21 ***Integrated Head Loss Test with Near-Field Settlement Credit:*** **Licensees should provide the one-hour or two-hour precipitate settlement values measured within 24 hours of head loss testing.**

Ameren Missouri chemical effects head loss testing did not credit near field settling.

3.o.2.22 ***Integrated Head Loss Test with Near-Field Settlement Credit:*** **Licensees should provide a best estimate of the amount of surrogate chemical debris that settles away from the strainer during the test.**

Ameren Missouri chemical effects head loss testing did not credit near field settling.

3.o.2.23 ***Head Loss Testing Without Near Field Settlement Credit:*** **Licensees should provide an estimate of the amount of debris and precipitate that remains on the tank/flume floor at the conclusion of the test and justify why the settlement is acceptable**.

Settled particulate was collected and weighted. For the FDL and TB tests 2.4 kg and 2.1 kg settle, which is less than 1% of the particulate mass tested.

Particulate that was collected and weighted at the end of the tests had multiple opportunities at transport by being re-suspended from agitation before settling at the bottom of the mixing region between the mixing nozzle and the strainer pit. A photograph of the deposition pattern at the end of the TB test is provided in Figure 3.o-2. A similar pattern was observed at the conclusion of the FDL test. The makeup of the settled debris is difficult to determine (i.e., it isn't appropriate to assume equal distribution among the batches).

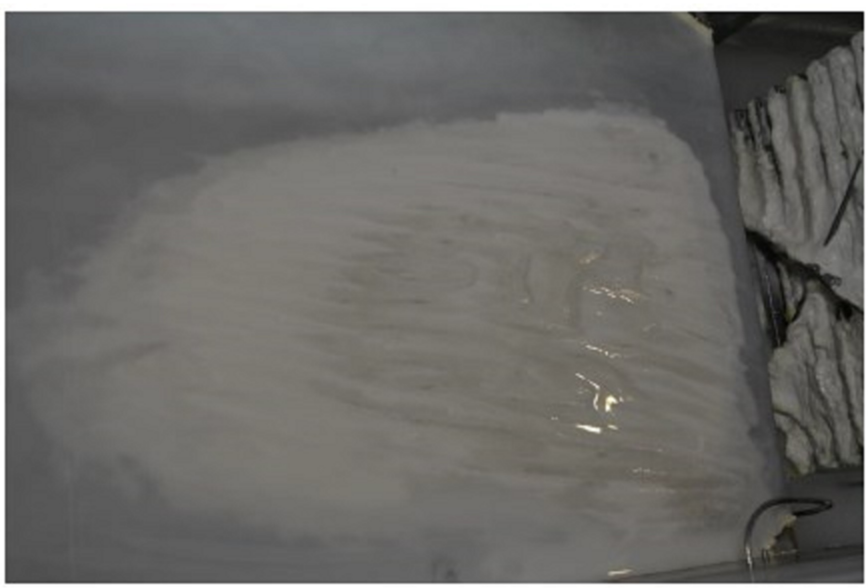


Figure 3.o-2: Settled Particulate at the Conclusion of the Thin Bed Test

3.o.2.*24 Head Loss Testing Without Near Field Settlement Credit:* Licensees should provide the one-hour or two-hour precipitate settlement values measured and the timing of the measurement relative to the start of head loss testing (e.g., within 24 hours).

All chemical product used in head loss testing was confirmed by test procedure to meet the settling criteria established in WCAP-16530-NP, and all chemical product was introduced to the head loss test loop within 24 hours after passing a settling test. Repeat settling tests were performed in the rare case that chemical product was prepared more than 24 hours before it was needed for introduction to the head loss test loop.

3.o.2.25 *Test Termination Criteria:* Provide the test termination criteria

The test termination criteria is less than a 1% change in head-loss per hour.

3.o.2.26 *Data Analysis:* Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.

Pressure curve as a function of time for the FDL and TB head loss tests are presented in Figures 3.o-3 to 3.o-6.

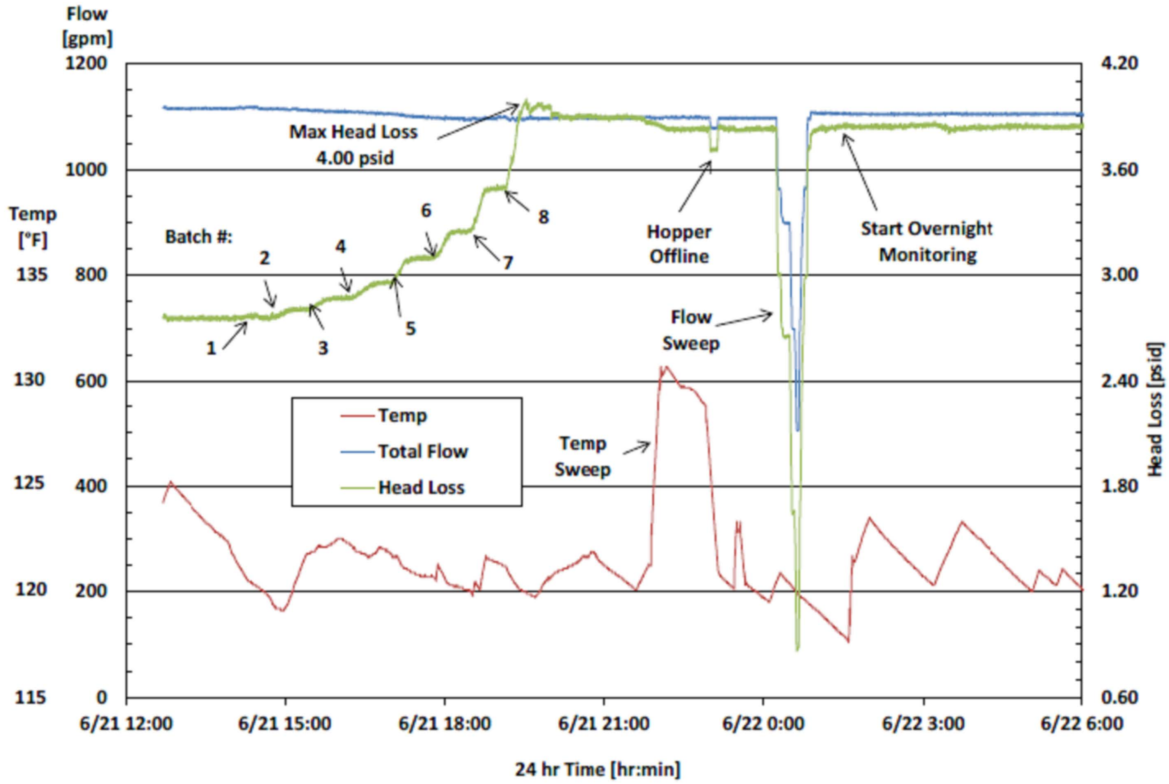


Figure 3.o-3: Full Debris Load Test Conventional Debris Timeline

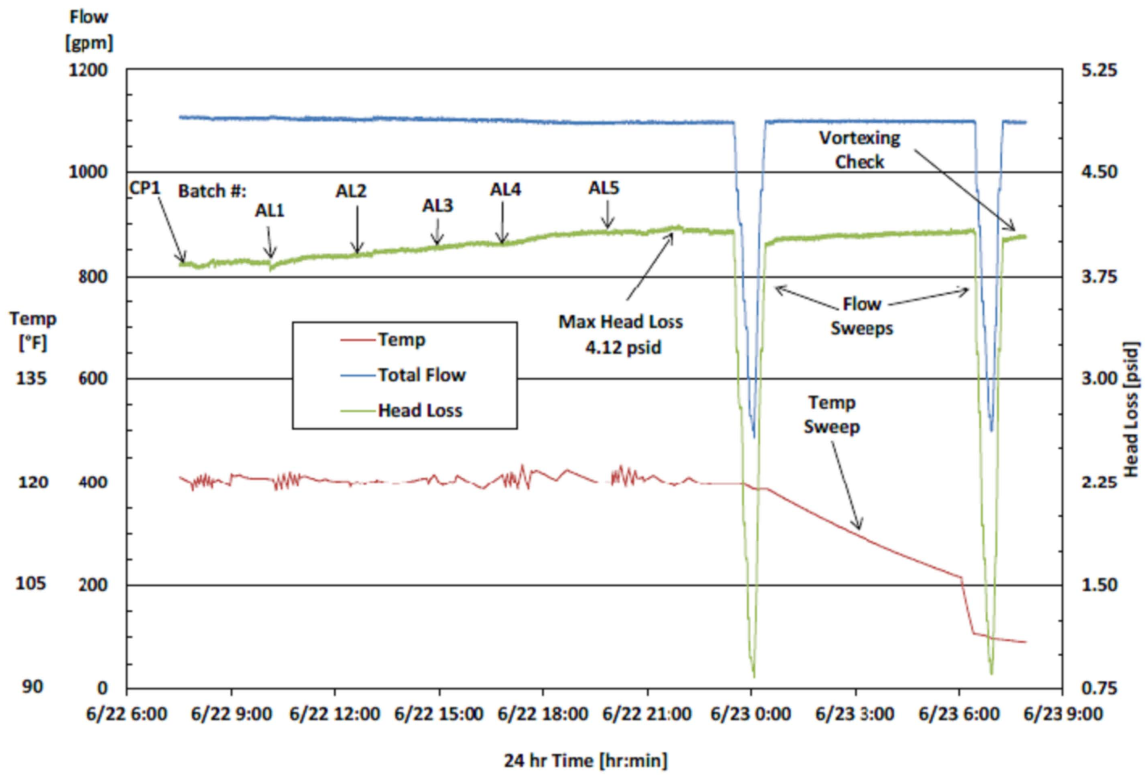


Figure 3.o-4: Full Debris Load Test Chemical Debris Timeline

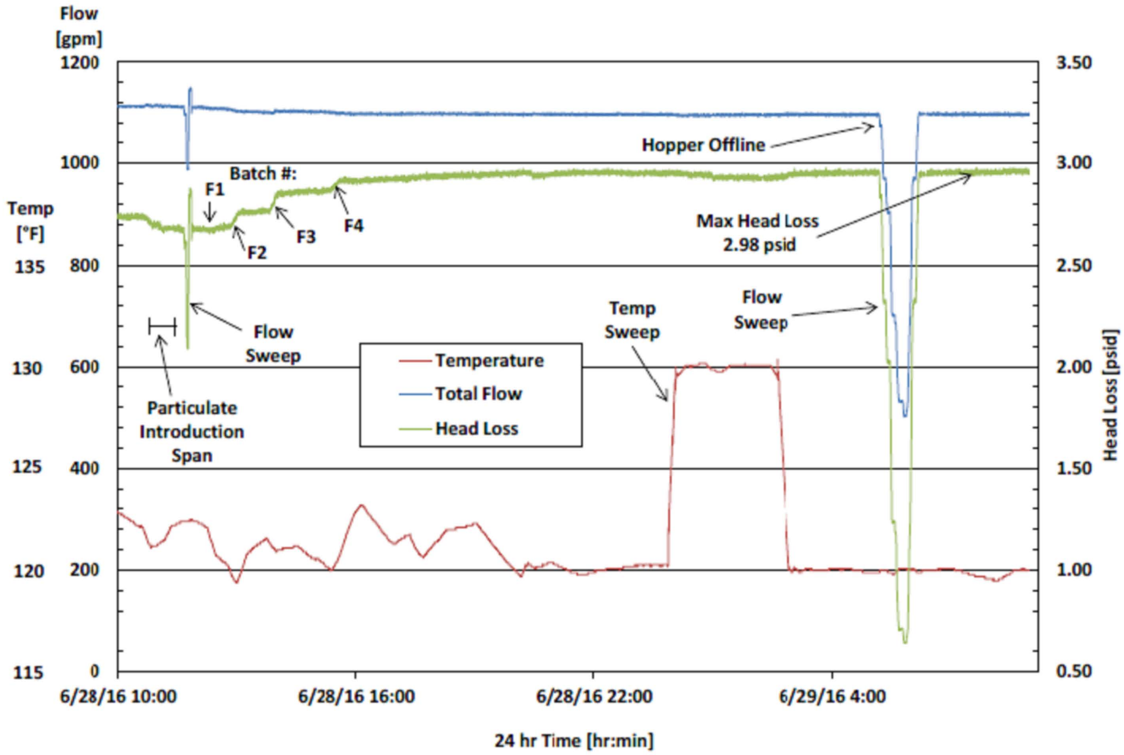


Figure 3.o-5: Thin Bed Test Conventional Debris Timeline

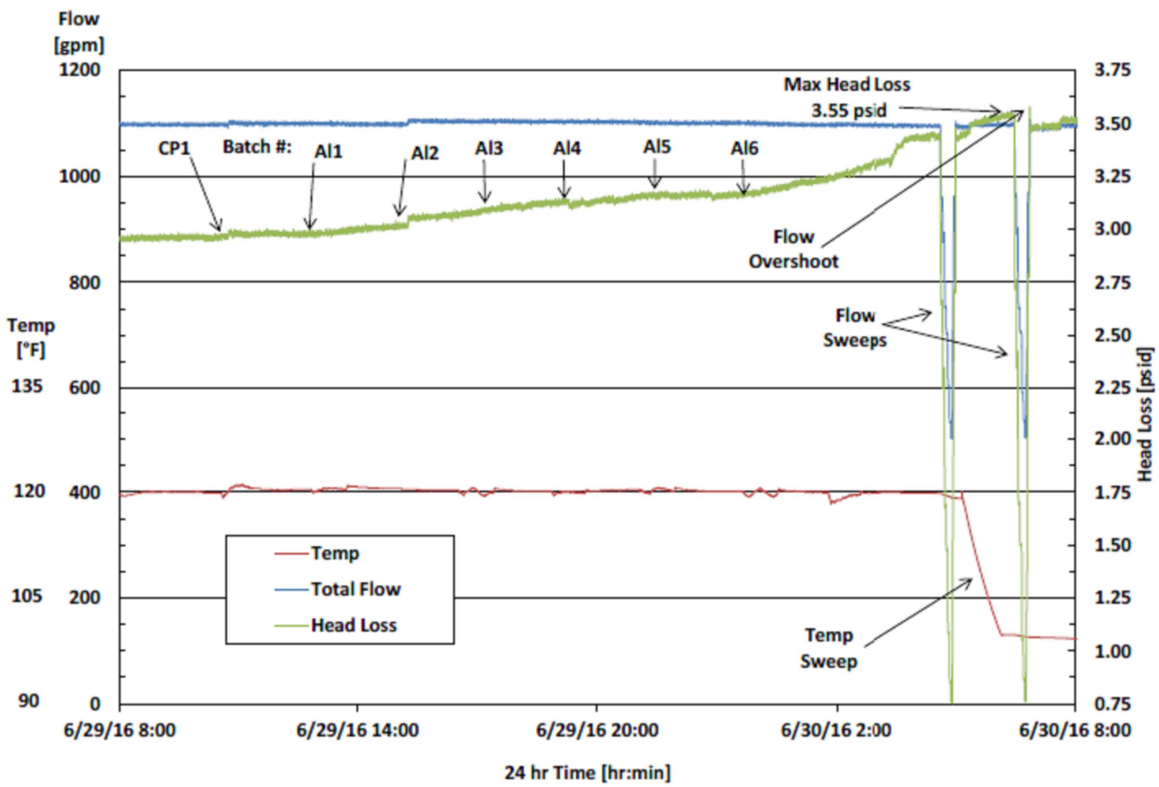


Figure 3.o-6: Thin Bed Test Chemical Debris Timeline

3.o.2.27 ***Data Analysis:*** **Licensees should explain any extrapolation methods used for data analysis.**

Data was not extrapolated.

3.o.2.28 ***Integral Generation (Alion):***

Ameren Missouri did not perform Alion-style Integral Generation Testing.

3.o.2.29 ***Tank Scaling / Bed Formation:*** **Explain how scaling factors for the test facilities are representative or conservative relative to plant-specific values.**

Ameren Missouri did not perform Alion-style Integral Generation Testing.

3.o.2.30 ***Tank Scaling / Bed Formation:*** **Explain how bed formation is representative of that expected for the size of materials and debris that is formed in the plant-specific evaluation.**

Ameren Missouri did not perform Alion-style Integral Generation Testing.

3.o.2.31 ***Tank Transport:*** **Explain how the transport of chemicals and debris in the testing facility is representative or conservative with regard to the expected flow and transport in the plant-specific conditions**

Ameren Missouri did not perform Alion-style Integral Generation Testing.

3.o.2.32 ***30-Day Integrated Head Loss Test:*** **Licensees should provide the plant-specific test conditions and the basis for why these test conditions and test results provide for a conservative chemical effects evaluation.**

Ameren Missouri did not perform Alion-style Integral Generation Testing.

3.o.2.33 ***30-Day Integrated Head Loss Test:*** **Licensees should provide a copy of the pressure drop curve(s) as a function of time for the testing of record.**

Ameren Missouri did not perform Alion-style Integral Generation Testing.

3.o.3.34 ***Data Analysis Bump Up Factor:*** **Licensees should provide the details and the technical basis that show why the bump-up factor from the particular debris bed in the test is appropriate for application to other debris beds.**

Ameren Missouri did not perform Alion-style Integral Generation Testing.

3.p. Licensing Basis

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the sump evaluation or plant modifications.

Provide the information requested in GL 04-02 Requested Information Item 2(e) regarding changes to the plant licensing basis. The effective date for changes to the licensing basis should be specified. This date should correspond to that specified in the 10 CFR 50.59 evaluation for the change to the licensing basis.

> *GL 2004-02 Requested Information Item 2(e)*
> *A general description of and planned schedule for any changes to the plant licensing bases resulting from any analysis or plant modifications made to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this GL. Any licensing actions or exemption requests needed to support changes to the plant licensing basis should be included.*

The information in this section revises information previously provided by Ameren Missouri to GL 2004-02 Requested Information Item 2(e) (Reference [2]).

Response to 3.p., Item 2(e). A general description of and planned schedule for any changes to the plant licensing bases resulting from any analysis or plant modifications made to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this GL. Any licensing actions or exemption requests needed to support changes to the plant licensing basis should be included.

Ameren Missouri is in the process of implementing licensing basis changes to support overall resolution of GSI-191 and GL 2004-02. These licensing basis changes include those associated with procedures and physical plant modifications, with changes to TS, with exemptions to certain regulations, and with analyses and evaluations.

The plant licensing basis changes due to procedures and plant modifications were evaluated against the current licensing basis, as well as the future licensing basis that will be in effect following implementation of the actions in the GL 2004-02 corrective action package. Procedure and plant modifications that have been implemented are described in section 2.

In Reference 23, Ameren Missouri requested a license amendment to revise TS 3.5.2, "ECCS - Operating," to support replacement of the containment recirculation sumps inlet trash racks and screens with the PCI Sure-Flow® replacement strainers described in section 3.j above. The approved amendment (Reference 24) revises

Surveillance Requirement 3.5.2.8 by replacing the phrase "trash racks and screens" with the word "strainers."

The analyses and evaluations supporting the GL 2004-02 corrective actions will become part of the plant licensing basis upon complete implementation of the GL 2004-02 corrective action package. See Enclosure 2 for the amendment request, TS changes, and FSAR changes.

All changes to the current licensing basis will be described in the Callaway FSAR in accordance with the requirements of 10 CFR 50.71(e).

4 References

[1] NEI 04-07 Rev. 0, "Vol. 1 Pressurized Water Reactor Sump Performance Evaluation Methodology, Vol. 2 Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Revision 0, December 6, 2004," U.S. Nuclear Regulatory Commission, December 2004.

[2] AmerenUE Letter ULNRC-05481, "Response to Request for Additional Information Re: Response for NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors'," (ADAMS Accession No. ML080810491) dated February 29, 2008.

[3] MEMO-9143-WMC-2K17-01, Rev 0, "MSLB MFLB Conditional Sump Failure Probabilities," April 2017.

[4] ALION-REP-ALION-2806-01, Rev. 4, "Insulation Debris Distribution for use in GSI-191 Resolution," Alion Science and Technology, May 2009.

[5] ML100570364, "Nuclear Regulatory Commission Conclusions Regarding Pressurized Water Reactor Owners Group Rsponse to Request for Additional Information Dated January 25, 2010 Regarding Licensee Debris Generation Assumptions for GSI-191," Nuclear Regulatory Commission, February 2010.

[6] WCAP-16710-P Rev 0, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON Insulation for Wolf Creek and Callaway Nuclear Operating Plants," October 2007.

[7] ML082050433, "Indian Point Energy Center Corrective Actions for Generic Letter 2004-02".

[8] NUREG/CR-6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," Los Alamos National Laboratory, February 2003.

[9] ALION-CAL-CEC-9143-017, "Callaway Risk-Informed Debris Transport Calculation," Alion Science and Technology, November 2016.

[10] 1162CECGSI-R2-00, Rev. 0, "Callaway Energy Center Head Loss Technical Report," March 2018.

[11] WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump FLuids to SUpport GSI-191," Westinghouse, March 2008.

[12] TDI-6002-05 / TDI-6003-05, Rev. 4, "Clean Head Loss - Wolf Creek / Callaway," Performance Contracting Inc (PCI), April 2008.

[13] ZZ-525 Rev 001 Addendum 5, "Containment Temperature-Pressure Sensitivities During Main Steam Line Break and Large Break Loss of Coolant Accident for Containment Cooler Energy Removal Capability (CAR #20128648)," October 2013.

[14] Technical Specification 3.6.4, "Containment Pressure," Amendment No. 202.

[15] 06-0413, "Design Basis Accident Testing of Coating Samples from Unit 1 Containment TXU Comanche Peak SES," April 2006.

[16] ML080230462, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Coatings Evaluations," Mach 2008.

[17] 01252178, "Unqualified Containment Coating Testing Carboline 193LF/191HB Applied to SP-3 Cleaned Bare Carbon Steel RF22," January 2018.

[18] WCAP-16406-P-A, Rev. 1 (Proprietary), "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Westinghouse Electric Company LLC, March 2008.

[19] ALION-CAL-CEC-9345-003 R0, "Strainer Penetration Test Report," Alion Science and Technology, 2018.

[20] ALION-CAL-CEC-9143-020 R0, "Callaway Energy Center Dowstream Ex-Vessel Effects Evaluation for ECCS Components," Alion Science and Technology, October 2018.

[21] WES004-PR-01, Rev. 2, "Evaluation of Containment Recirculation Sump Downstream Effects for the Wolf Creek Electric Generating Station and the Callaway Nuclear Plant," Enercon Services Inc., May 2006.

[22] WCAP-11534 (Proprietary), "Evaluation of Containment Coatings for Sequoyah Unit 2," Westinghouse Electric Corporation, September 1987.

[23] CN-CSA-05-20 Rev. 2 (Proprietary), "Wolf Creek/Callaway Sump Debris Downstream Effects Evaluation for ECCS Equipment," Westinghouse Electric Company LLC, September 2008.

[24] CN-CSA-05-49 Rev. 2 (Proprietary), "Callaway/Wolf Creek GSI 191 Down Stream Effects Debris Ingestion Evaluation," Westinghouse Electric Company LLC, August 2008.

[25] LTR-SEE-I-08-138, Rev. 0 (Proprietary), "Evaluation of Potential for Fibrous Debris to Clog Cyclone Separator Ports at Callaway and Wolf Creek Nuclear Plants," Westinghouse Electric Company LLC, September 2008.

[26] CN-SEE-I-08-67 Rev. 0 (Proprietary), "Wolf Creek/Callaway Mechanical Seal Evaluation for ECCS Pumps," Westinghouse Electric Company LLC, September 2008.

[27] WCAP-17788-NP R0, "Comprehensive Analysis and Test Program for GSI-191 Closure," Westinghouse, July 2015.

[28] ALION-CAL-CEC-9143-019, Rev. 0, "WCAP-17788 In-Vessel Debris Effects Evaluation," 2018.

[29] SERCO-CAL-CEC-9143-024, Rev. 0, "Strainer Penetration Fiber Time History Calculation," May 2020.

[30] WCAP-17788-P, Volume 1, Rev. 0 (Proprietary), "Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090)," July 2015.

[31] BN-16, Rev.1, "RWST Drain-down during Transfer to Cold Leg Recirculation," Ameren Missouri Calculation, August 2006.

[32] CN-SEE-02-11, "SCP Minimum Switchover Times," Westinghouse Electric Company Calculation.

Attachment 3-3

Risk-Informed Basis

I Introduction

Risk over Deterministic (RoverD) is a method that follows the guidance of Regulatory Guide (RG) 1.174 (NRC, 2018) to assess the risk associated with concerns raised in Generic Letter (GL) 2004-02. RoverD requires a head-loss test that successfully achieves all deterministic strainer performance metrics, while the quantity of low-density fiber glass (LDFG) tested is a risk-based metric. CASA Grande is used to evaluate the magnitude of loss of coolant accidents (LOCAs) required to exceed the risk-based metric, referred to as the fiber threshold. The fiber threshold is set low to underestimate the true level where functionality may be lost, so that risk for strainer failure is overestimated. Even when adopting a low threshold for failure, the risk is shown to be very small (Reference [1]).

The risk-based metric is used to classify scenarios as 'deterministic' or 'risk informed' as illustrated in Figure 1-1. Deterministic scenarios are those in which LDFG estimated to arrive on the emergency strainers by CASA Grande do not exceed the fiber, or risk-based, threshold. Risk-informed scenarios occur when LDFG estimated to arrive at the ECCS strainers exceeds the amount of LDFG used in strainer testing, and the risk contribution of these breaks is evaluated by CASA Grande against RG 1.174 quantitative criteria for core-damage frequency {CFD, ΔCFD} and large early-release frequency {LERF, ΔLERF}.

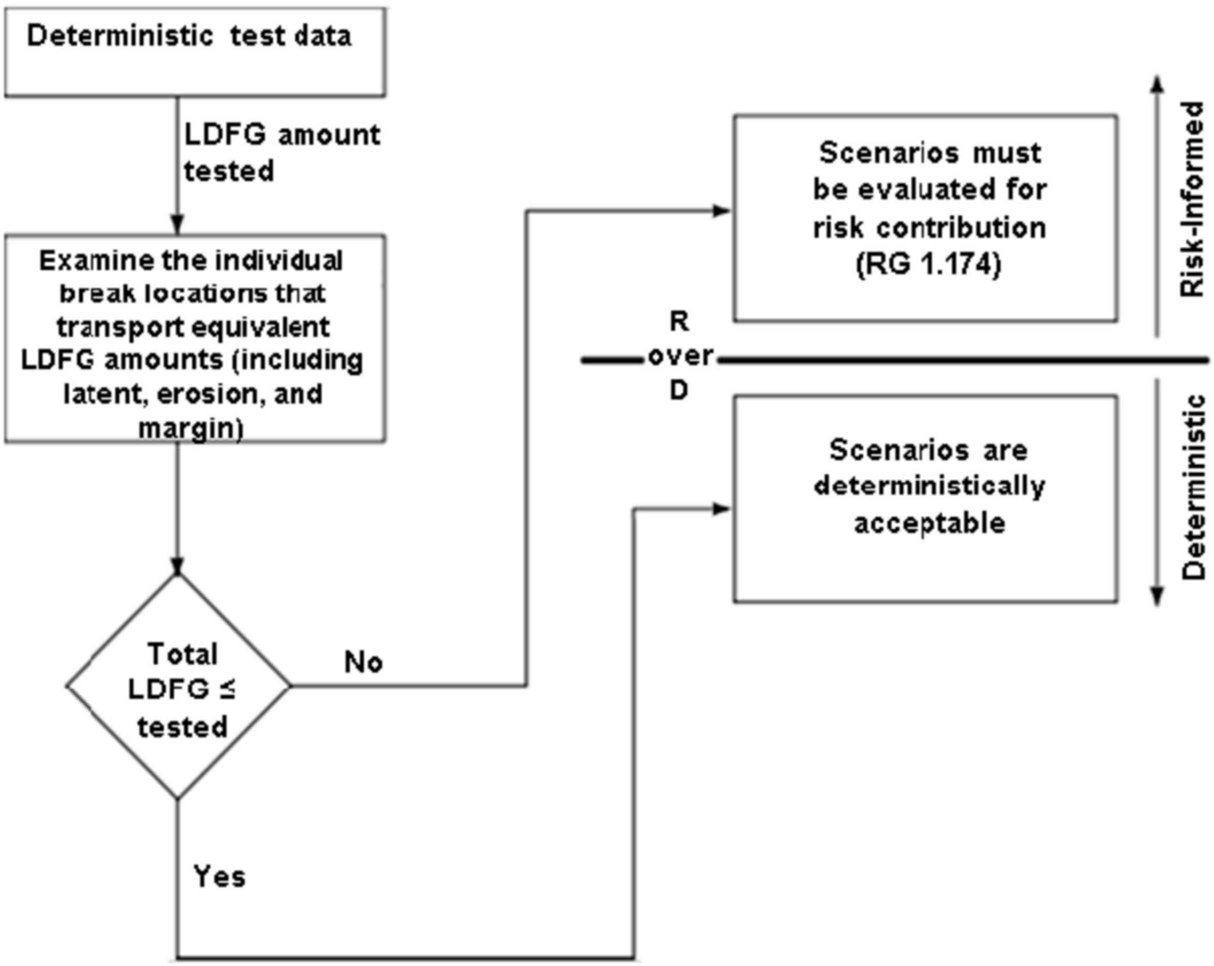
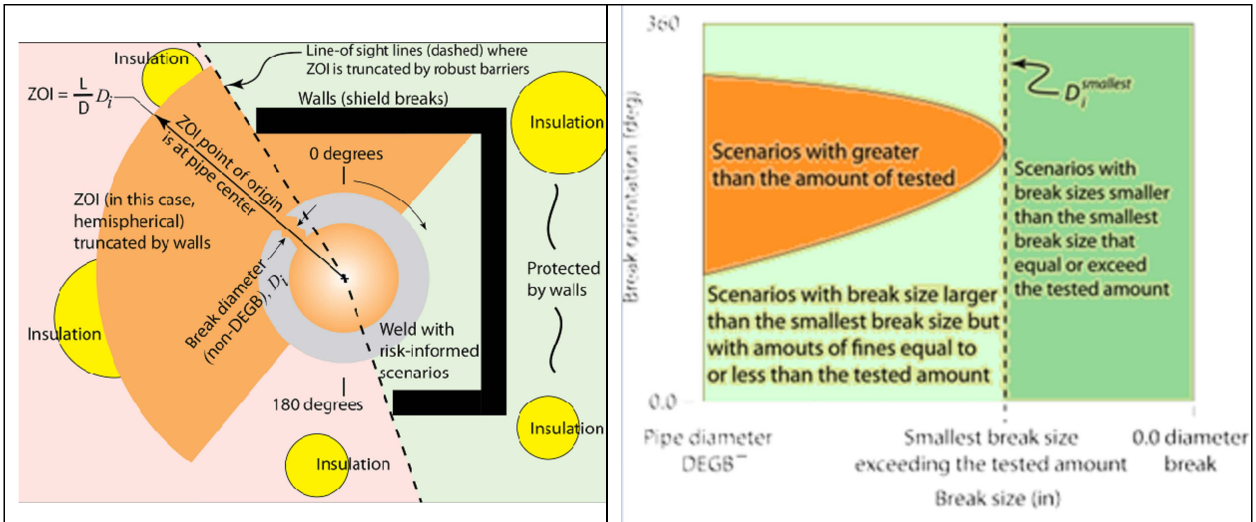


Figure 1-1: RoverD separates those scenarios that go to success deterministically from those that are assumed to go to failure and require risk-informed analysis

Scenarios are the result of exhaustive sampling for break sizes and orientations at weld locations to identify the smallest break size that would exceed the fiber threshold. Although some scenarios at a weld location with one or more scenarios in the risk-informed category may be successful, in RoverD, the frequency assigned at any risk-informed weld is the frequency associated with the smallest break size for that weld. As a consequence, some scenarios at weld locations may have break sizes larger than the smallest size, but do not produce more fines than the tested amount. That is, some scenarios for any particular non-double-ended guillotine break (DEGB) risk-informed weld may be successful (in fact, many may be successful). The nature of this kind of behavior is shown in Figure 1-2.



(a) Conceptual illustration of a break with diameter D_i where robust barriers truncate the ZOI such that breaks larger than the smallest break exceeding the tested amount of LDFG result in less amounts of LDFG.

(b) Depiction on the {angle of orientation, break size} phase plane of the smallest break size and the resulting amount of LDFG. Some areas on the phase plane at break sizes larger than the smallest have less than the tested amount of LDFG.

Figure 1-2: Hypothetical break and the LDFG production for different break sizes and orientations showing how some break sizes larger than the smallest break size in a risk-informed weld location can have less LDFG produced.

The term 'deterministic' refers to any scenario that is bounded by tests and do not contribute to risk. Using test data that includes breaks that are not bounded by test data results in scenarios that would fall outside the bounding envelope of the tests. The risk for any such scenarios is required to meet a 'very small' threshold as shown in Figure 1-3.

In the following, the various analyses required to complete a RoverD assessment are summarized. The steps required to complete a RoverD analysis are summarized in Section 2.

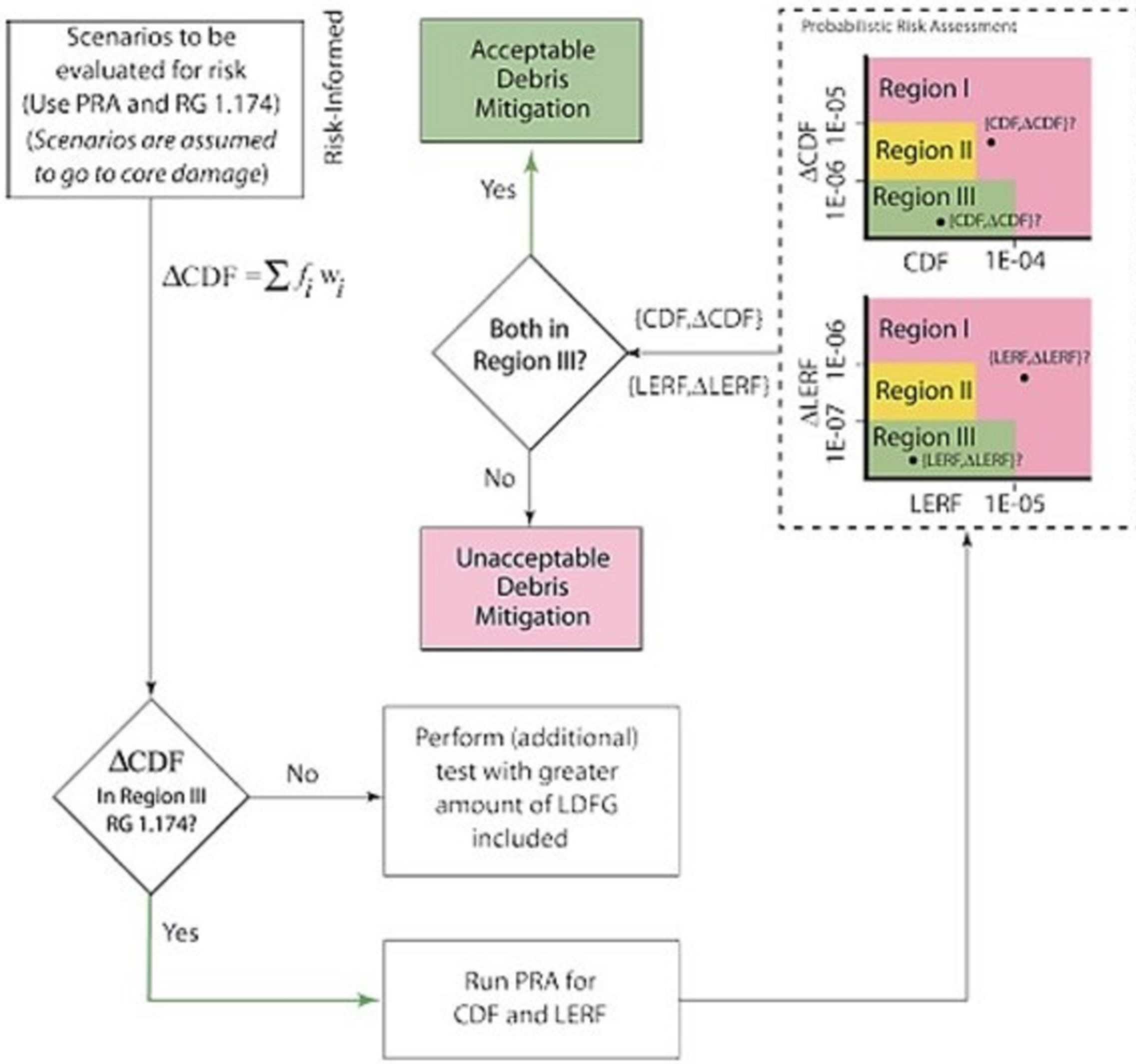


Figure 1-3: Flow chart showing the RoverD evaluation process following categorization of scenarios to determine risk acceptability. In this description, the frequency, $\boldsymbol{f_i}$, of break at any location is evaluated based on its diameter using NUREG-1829.

2 RoverD Methodology Summary

RoverD involves the following steps to assess the risk associated with the concerns raised in GL 2004-02:

1. Perform a deterministic head-loss test where the quantity of LDFG tested is implemented as a risk-based metric. Also, the head-loss test must be successful for all strainer performance metrics such as net positive suction head (NPSH), deaeration, potential to flash, vortex formation, and structural requirements.

2. Simulate CASA Grande to:

   a. Equally distribute NUREG-1829 break frequencies to all break locations. This method is known as the top-down approach.

   b. Determine the smallest break, known as the 'critical break size', at each location that generates and transports LDFG in excess of the fiber threshold and assume core damage at these locations.

      i. If a DEGB at a specified location does not generate and transport LDFG to the strainer in excess of the fiber threshold, the break is counted as a success, does not contribute to risk, and is classified as 'deterministic' or 'non-critical'. Note, if a DEGB is counted as a success, all partial breaks would be successful as well. Partial breaks generate less debris than a DEGB.

      ii. If a DEGB break at a specified location generates and transports LDFG to the strainer in excess of the fiber threshold, the welds are classified as 'risk-informed' or 'critical'. The critical break size at this location is determined by searching partial breaks at 0.1 inch break size increments and 1° angular increments. The contribution to risk is determined by the difference in exceedance frequency between the critical break size and the inner weld diameter (scaled by the number of welds in this size range).

   c. Aggregate the exceedance frequencies for all 'risk-informed' breaks.

3. Determine risk associated with secondary risk contributors (SRC), which are events with initiators other than pipe ruptures at Class-I welds between the reactor pressure vessel (RPV) and an isolation valve. SRC considered in this analysis are listed failure of isolation valves, secondary line breaks, spurious and failed-open valves, and mechanical LOCAs (pump seal LOCAs) Refer to the

responses to Questions 34 and 35 in Enclosure 5 for additional information regarding secondary risk contributor screening.

4. Determine the risk associated with additional risk contributors that challenge the successful operation of integral equipment during an event. Additional risk contributors are ex-vessel downstream wear, strainer structural analysis, and in-vessel effect.

5. Evaluate the risk contribution from all events with RG 1.174 quantitative criteria for core-damage frequency {CDF, ΔCDF} and large early-release frequency {LERF, ΔLERF}.

2.1 **Weld Populations and Sensitivity Studies Overview**

Class I welds between the RPV and first isolation valve are included for the baseline LOCA simulations where all the NUREG-1829, 25-year frequencies are distributed to this population of welds with a geometric weighting. Class I welds beyond the first isolation valve require an isolation valve failure to have a LOCA and are classified as SRC. All the NUREG-1829, 25-year frequencies are also distributed to this population of welds with a geometric weighting. Thus, NUREG-1829 frequencies are distributed in totality twice, which results in an overestimate of risk. Also, sensitivities are performed by varying the following parameters: DEGB or continuum break models, 25-year or 40-year NUREG-1829 frequencies, arithmetic or geometric weighting, and addition insulation on valves. Refer to the responses to Questions 36 and 38 in Enclosure 5 for additional information regarding sensitivity studies.

3 Head-Loss Tests

Full debris load and thin bed head-loss tests were conducted at Alden Research Laboratories in 2016. The tests were conducted adhering to guidance for deterministic closure. The full debris load test targeted maximum chemical precipitate and particulate loads, while the fiber load is a risk based metric that determines the success criteria for an individual break. The full debris load test achieved successful head-loss results with 300 lbm of LDFG fines. Therefore, the RoverD limit is 300 lbm. For more details regarding the head-loss tests refer to Attachment 3-2.

4 LDFG Debris Generation

LDFG is the only debris that is a risk metric. For details regarding other debris types, see Attachment 3-2, the deterministic basis. The sources for LDFG are:

- Latent Fiber
- Fiber Margin

- Break-dependent NUKON® and Thermal-Wrap®

A latent fiber mass of 30 lbm is attributed to every break as specified by guidance (Reference [2, 3]). Plant walkdown data indicates that the actual quantity of latent fiber is less than 30 lbm. Therefore, this assumption results in larger estimates of LDFG and is conservative.

A fiber margin of 50 lbm (with 100% transport) is applied to all postulated breaks for the baseline case. This 50 lbm of fiber is in addition to ZOI-generated and latent fiber sources. This 50-lbm margin provides additional assurance (not required by regulatory guidance) that the quantified change in core damage risk is conservative and that break scenarios where the strainer is determined by analysis to be successful have unquestionably successful outcomes. Furthermore, this 50 lbm fiber margin may be used to support future discoveries of additional fiber sources in containment without invalidating the current analysis.

NUKON® and Thermal-Wrap® are break-dependent LDFG debris that may be generated from a LOCA. NEI (Reference [2, 3]) documented an acceptable methodology for determining the amount of debris generated in a LOCA of any particular size by defining a zone of influence (ZOI). Within the ZOI, specific size distributions of LDFG particles can be estimated (Figure 4-1).

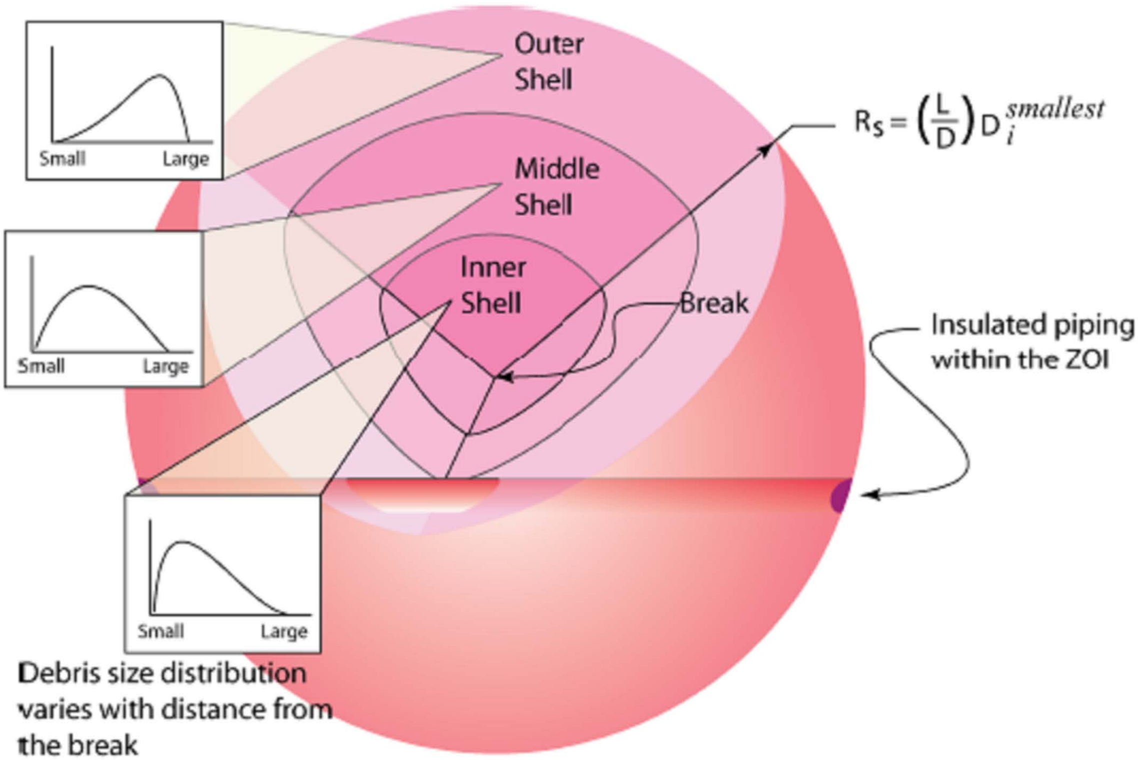


Figure 4-1: Conceptual illustration of three zones of destruction potential within the ZOI showing how the debris distribution shifts towards larger sizes further from the break.

Each of the fiber insulation types has ZOIs based on jet testing. The maximum ZOIs used for fibrous insulations are summarized in Table 4-1 and are based on the standard deterministic approach promulgated by NEI 04-07 (Reference [2, 3]), while the debris size distributions for inner shells are based on proprietary Alion report ALION-REP-ALION-2806-01 “Insulation Debris Size Distribution for use in GSI-191 Resolution” (Reference [4]). Fiber ZOIs used for the Callaway analysis are equivalent to the pilot-plant’s fiber ZOIs.

Table 4-1: Summary of the maximum ZOI size for fiber-producing insulation

Insulation Type	Max ZOI $\left(\frac{radius}{break\ diameter}\right)$	Reference
NUKON®	17.0	NEI (Reference [2, 3])
Thermal-Wrap®	17.0	NEI (Reference [2, 3])

As previously stated, the ZOIs for NUKON® and Thermal-Wrap® insulations are shells with different percentages of debris sizes created within each shell. Along with fiber fines produced, debris sizes are calculated from each shell for small pieces, large pieces, and intact blankets.

All destroyed insulation volume was converted to mass using the manufactured densities (Reference [2]):

- NUKON® 2.4 $\frac{lbm}{ft^3}$
- Thermal-Wrap® 2.4 $\frac{lbm}{ft^3}$

5 LDFG Transport

Once amounts and distributions of fiber types are known, debris transport fractions are used to estimate the amount and size of debris that accumulates on the strainer. LDFG, latent fiber, and fiber margin overall debris transport fractions are presented in Table 5-1 because these are the debris types that contribute to the risk metric. For details regarding other debris types and the phases of debris transport, such as blowdown, pool fill, washdown, or recirculation debris transport, refer to the deterministic basis in Attachment 3-2.

Table 5-1: Overall debris transport fractions

Debris Type	Debris Size	Debris Transport Fraction by Break Location				Implemented Fraction
		Steam Generator Compartment	Annulus	Upper Pressurizer Compartment	Lower Pressurizer Compartment	
LDFG	Fines	99%	99%	99%	99%	99%
	Small Pieces (<6”)	70%	60%	68%	64%	70%
	Large Pieces (>6”)	66%	64%	0%	66%	66%
	Fines Eroded from Smalls	100%	100%	100%	100%	100%
	Fines Eroded from Larges	100%	100%	100%	100%	100%
Latent Fiber	Fines	96%	96%	96%	96%	96%
Fiber Margin	Fines	100%	100%	100%	100%	100%

As small and large pieces transport to the strainers or the location where they settle (for example, on grating, in a quiescent part of the containment building pool, etc.), fines may erode or dislodge from the small and large pieces and readily transport the strainers. Table 5-2 displays the amount of fines eroded from small and large pieces.

Table 5-2: LDFG debris erosion fractions

Debris Type	Debris Size	Debris Transport Fraction by Break Location				Implemented Fraction
		Steam Generator Compartment	Annulus	Upper Pressurizer Compartment	Lower Pressurizer Compartment	
LDFG	Fines Eroded from Smalls	0%	1%	0%	0%	**1%**
	Fines Eroded from Larges	3%	4%	0%	3%	**4%**

All eroded fines transport to the strainer at 100%.

6 LOCA Frequencies

Break frequency data from NUREG-1829 are analyzed using both the geometric-aggregated and arithmetic-aggregated means, medians, fifth, and ninety-fifth percentiles of the elicited data. Break-size-dependent annual exceedance frequency estimates are provided for both the 25-year and 40-year fleet operation averages. Table 6-1 presents the 25-year exceedance frequencies and Table 6-2 presents the 40-year exceedance frequencies, taken respectively from Tables 7.13 and 7.19 of NUREG-1829 (Reference [5]).

Table 6-1: NUREG-1829 25-year LOCA exceedance frequencies

Break Size (in)	Geometric (1/year)				Arithmetic (1/year)			
	5th	50th	Mean	95th	5th	50th	Mean	95th
0.500	6.8E-05	6.3E-04	1.9E-03	7.1E-03	8.1E-04	4.8E-03	1.0E-02	3.6E-02
1.625	5.0E-06	8.9E-05	4.2E-04	1.6E-03	4.2E-05	7.0E-04	3.0E-03	1.2E-02
3.000	2.1E-07	3.4E-06	1.6E-05	6.1E-05	1.3E-06	1.9E-05	7.3E-05	2.9E-04
7.000	1.4E-08	3.1E-07	1.6E-06	6.1E-06	6.9E-08	1.3E-06	9.4E-06	3.0E-05
14.000	4.1E-10	1.2E-08	2.0E-07	5.8E-07	9.9E-09	2.6E-07	2.4E-06	7.2E-06
31.000	3.5E-11	1.2E-09	2.9E-08	8.1E-08	5.9E-09	1.5E-07	1.5E-06	5.2E-06

Table 6-2: NUREG-1829 40-year LOCA exceedance frequencies

Break Size (in)	Geometric (1/year)				Arithmetic (1/year)			
	5th	50th	Mean	95th	5th	50th	Mean	95th
0.500	7.0E-05	7.2E-04	2.1E-03	7.9E-03	5.2E-04	4.2E-03	9.2E-03	3.3E-02
1.625	6.1E-06	1.2E-04	5.8E-04	2.2E-03	3.9E-05	7.6E-04	3.5E-03	1.3E-02
3.000	4.8E-07	7.6E-06	3.6E-05	1.4E-04	1.4E-06	2.2E-05	1.4E-04	5.1E-04
7.000	2.8E-08	6.6E-07	3.6E-06	1.4E-05	1.0E-07	2.0E-06	2.1E-05	6.8E-05
14.000	1.0E-09	2.8E-08	4.8E-07	1.4E-06	1.4E-08	3.3E-07	4.0E-06	1.0E-05
31.000	8.7E-11	2.9E-09	7.5E-08	2.1E-07	6.1E-09	1.5E-07	1.9E-06	5.5E-06

CASA Grande uses LOCA exceedance frequencies to derive frequencies for critical breaks. Critical break frequencies are then used to aggregate per weld contributions to ΔCDF for all breaks generating and transporting LDFG debris quantities greater than the tested RoverD failure limits.

Note that Bounded Johnson distributions have been fit to the tabulated 25-year frequency statistics to allow risk estimates to be generated for any uncertainty percentile (not just the mean, 5th, 50th, and 95th percentiles). The Bounded Johnson distributions are used to create the blue dots in Figure 7-1 and are supplemental information. The Bounded Johnson distribution has a range defined by minimum and maximum parameters and has both a shape parameter and a scale parameter. These four parameters are adjusted to attain the best possible agreement with the tabulated exceedance frequency statistics. Use of the Bounded Johnson fits provides additional insights for consideration, but does not affect the accepted RoverD methodology for total ΔCDF risk estimation.

The maximum LDFG transported by each critical weld was determined by evaluating 360 jet directions at each critical break size, identified by searching in increments of one angular degree. The total LDFG transported for each postulated break is the sum of ZOI-generated debris, latent fiber debris, and the fiber safety margin. Finally, each critical weld contribution to ΔCDF is calculated based on the exceedance frequency for the critical break size determined using the NUREG-1829 initiating event frequency data.

7 Baseline Results

7.1 Baseline ΔCDF

A summary of ΔCDF estimates the change in number of core damage events per year for the continuum break model based on geometric 25-year LOCA frequencies as provided in Table 7-1 below. The ΔCDF estimates presented in Table 7-1 correspond to the mean, 5th, 50th, and 95th percentiles of the geometric 25-year LOCA exceedance frequencies provided in Table 6-1, which provides estimates across the standard range of uncertainty.

Table 7-1: RoverD ΔCDF results for baseline scenario

Statistic	5th	50th	Mean	95th
ΔCDF (# core damage events / year)	4.01E-09	9.04E-08	5.37E-07	1.95E-06

To illustrate estimated ΔCDF for the full range of uncertainty, Bounded Johnson distributions fit to NUREG-1829 exceedance frequencies were used to calculate ΔCDF for a discrete set of 120 percentiles that are displayed in Figure 7-1 as blue dots. The geometric method of aggregation is considered the most appropriate method for aggregating expert elicitations for LOCA exceedance frequencies. The arithmetic aggregation is implemented for several sensitivity cases in Section 9.1. Figure 7-1 shows that approximately 88% of ΔCDF estimates are in Region III of Regulatory Guide 1.174 (Reference [1]) for the baseline case. With respect to uncertainty in the initiating event frequencies alone, these results indicate an 88% confidence that ΔCDF is less than 1.0E-6 core damage events per year (Region III cutoff from Reg. Guide 1.174). The black dots in Figure 7-1 indicate the 5th, 50th, mean, and 95th percentiles of ΔCDF uncertainty propagated from LOCA initiating event frequency uncertainty.

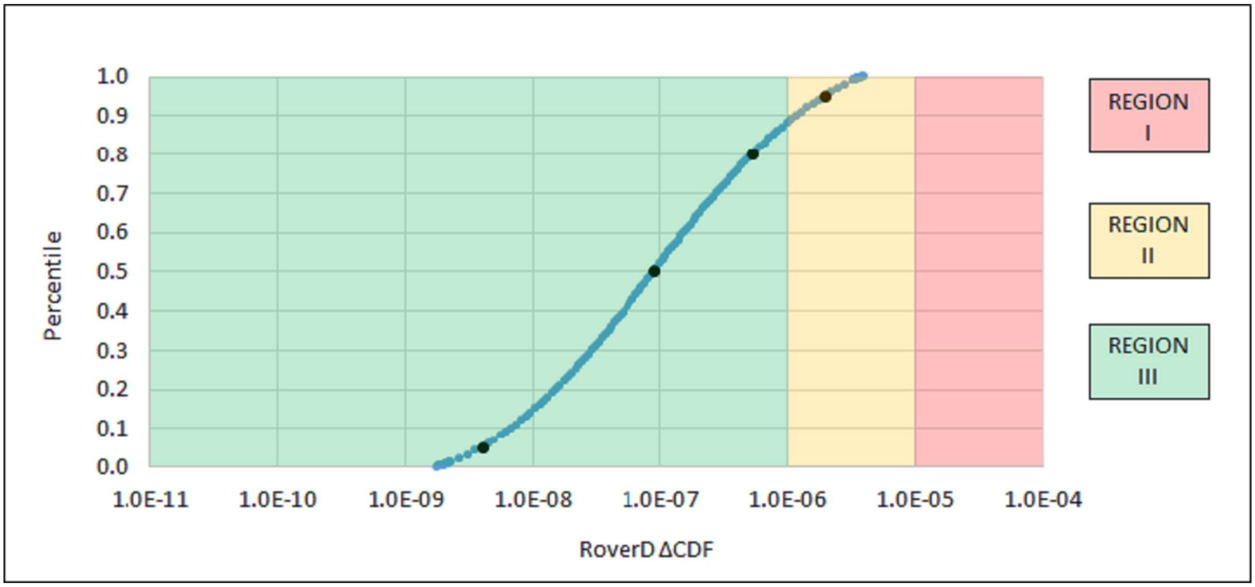


Figure 7-1: Distribution of RoverD ΔCDF for 25-year geometric mean frequencies

7.2 **Baseline ΔLERF**

The methodology for estimating ΔLERF (change in number of large early release events per year) utilizes the ratio of conditional LERF (CLERF) to conditional CDF (CCDF). The ratio of CLERF to CCDF is assumed to be 0.1, representing the conditional probability of large early release, given the occurrence of core-damage induced by a large break loss of coolant accident with containment sumps failed. (Approximately one in every ten core-damage events leads to large early release). Because GL 2004-02 debris-related phenomena do not directly challenge the containment building (which could lead to increased LERF), the ratio of ΔLERF to ΔCDF is assumed to be the same as the ratio of CLERF to CCDF. Estimates of ΔCDF reported above are attributed exclusively to GL 2004-02 debris phenomena, so the corresponding ΔLERF caused by GL 2004-02 phenomena can be calculated using the ratio of CLERF to CCDF. A summary of ΔLERF estimates for the continuum break model based on geometric 25-year LOCA frequencies is provided in Table 7-2. The mean estimate of ΔLERF is 5.37E-08 events per year and is also in Risk Region III as defined by Regulatory Guide 1.174 (Reference [1]).

Table 7-2: RoverD ΔLERF results for baseline scenario

Statistic	5th	50th	Mean	95th
ΔLERF (# large early release events/year)	4.01E-10	9.04E-09	5.37E-08	1.95E-07

7.3 **Baseline Weld List**

The critical weld list, as defined in the RoverD methodology, is a collection of welds where a postulated break generates and transports enough fibrous debris to exceed the RoverD failure threshold of 300 lbm. Table 7-3 lists the Class-I welds located between the RPV and the first isolation valve that were found to be capable of generating and transporting LDFG debris in excess of the RoverD test limit when 50 lbm of transported fiber safety margin are added to the predicted fiber inventory of every break scenario. The table includes the weld name, the smallest break size to fail, the maximum fiber transported for the smallest break to fail, the fiber margin (the difference between the RoverD failure threshold and the amount of fiber transported), and the per weld contribution to ΔCDF. Note, the per weld contributions to ΔCDF in the last column sum to equal the mean ΔCDF reported in Table 7-1.

Table 7-3: Baseline critical weld list for continuum model

#	Weld Location Name	Smallest Break Size to Fail (inches)	Fiber Transported at Smallest Break Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ΔCDF(1)
1	WELD EBB01B-RSG-OUTLET-SC010	11.855	300.091	-0.091	1.09E-08
2	WELD 2-BB-01-3065B-WDC-002-FW2	11.795	300.354	-0.354	1.11E-08
3	WELD 2-BB-01-F206	11.495	300.096	-0.096	1.20E-08
4	WELD 2-BB-01-S204-3	11.885	300.149	-0.149	1.08E-08
5	WELD 2-BB-01-F208	11.565	300.156	-0.156	1.18E-08
6	WELD 2-BB-01-S205-4	11.125	300.025	-0.025	1.31E-08
7	WELD 2-BB-01-F207	11.525	300.048	-0.048	1.19E-08
8	WELD 2-BB-01-S201-2	27.500	313.423	-13.423	0.00E+00(1)
9	WELD 2-BB-01-F201	10.855	300.254	-0.254	1.18E-08
10	WELD 2-BB-01-S202-2	13.275	300.183	-0.183	4.70E-09
11	WELD 2-BB-01-3065B-WDC-001-FW1	13.225	300.217	-0.217	4.86E-09
12	WELD EBB01B-RSG-INLET-SC010	13.255	300.190	-0.190	4.76E-09
13	WELD 2-EJ-04-FW9	10.500	327.631	-27.631	0.00E+00(1)
14	WELD 2-EJ-04-S018-C	10.500	329.261	-29.261	0.00E+00(1)
15	WELD 2-EJ-04-FW8	10.500	326.983	-26.983	0.00E+00(1)
16	WELD 2-EJ-04-S018-E	10.500	351.002	-51.002	0.00E+00(1)
17	WELD 2-EJ-04-F031	9.985	300.095	-0.095	1.14E-09
18	WELD EBB01A-RSG-OUTLET-SC010	10.905	300.032	-0.032	1.37E-08
19	WELD 2-BB-01-3065A-WDC-002-FW2	10.805	300.247	-0.247	1.40E-08
20	WELD 2-BB-01-F106	9.965	300.022	-0.022	1.60E-08
21	WELD 2-BB-01-S104-3	9.915	300.010	-0.010	1.61E-08
22	WELD 2-BB-01-F108	9.915	300.054	-0.054	1.61E-08
23	WELD 2-BB-01-S105-4	9.145	300.362	-0.362	1.78E-08
24	WELD 2-BB-01-F107	9.595	300.226	-0.226	1.68E-08
25	WELD 2-BB-01-S102-2	11.755	300.091	-0.091	9.45E-09
26	WELD 2-BB-01-3065A-WDC-001-FW1	11.525	300.508	-0.508	1.02E-08
27	WELD EBB01A-RSG-INLET-SC010	11.565	300.063	-0.063	1.00E-08
28	WELD 2-RV-302-121-A	27.325	300.076	-0.076	2.75E-11
29	WELD 2-BB-01-F102	26.975	300.068	-0.068	8.25E-11
30	WELD 2-BB-01-S101-2	27.500	345.081	-45.081	0.00E+00(1)

#	Weld Location Name	Smallest Break Size to Fail (inches)	Fiber Transported at Smallest Break Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ΔCDF(1)
31	WELD 2-BB-01-F101	9.475	300.219	-0.219	1.50E-08
32	WELD EBB01C-RSG-OUTLET-SC010	11.615	300.129	-0.129	1.16E-08
33	WELD 2-BB-01-3065C-WDC-002-FW2	11.515	300.400	-0.400	1.20E-08
34	WELD 2-BB-01-F306	10.945	300.219	-0.219	1.36E-08
35	WELD 2-BB-01-S304-3	11.295	300.226	-0.226	1.26E-08
36	WELD 2-BB-01-F308	11.255	300.364	-0.364	1.28E-08
37	WELD 2-BB-01-S305-4	10.585	300.050	-0.050	1.46E-08
38	WELD 2-BB-01-F307	11.165	300.014	-0.014	1.30E-08
39	WELD 2-BB-01-F301	11.415	300.700	-0.700	1.02E-08
40	WELD 2-BB-01-S302-2	13.405	300.053	-0.053	4.30E-09
41	WELD 2-BB-01-3065C-WDC-001-FW1	12.995	300.271	-0.271	5.58E-09
42	WELD EBB01C-RSG-INLET-SC010	13.015	300.404	-0.404	5.51E-09
43	WELD 2-BB-01-S402-2	12.385	300.334	-0.334	7.48E-09
44	WELD 2-BB-01-3065D-WDC-001-FW1	11.825	300.020	-0.020	9.23E-09
45	WELD EBB01D-RSG-INLET-SC010	11.875	300.188	-0.188	9.08E-09
46	WELD 2-BB-01-F401	9.905	300.507	-0.507	1.41E-08
47	WELD EBB01D-RSG-OUTLET-SC010	10.745	300.278	-0.278	1.42E-08
48	WELD 2-BB-01-3065D-WDC-002-FW2	10.635	300.075	-0.075	1.45E-08
49	WELD 2-BB-01-F406	9.845	300.122	-0.122	1.63E-08
50	WELD 2-BB-01-S404-3	9.695	300.179	-0.179	1.66E-08
51	WELD 2-BB-01-F408	9.605	300.489	-0.489	1.68E-08
52	WELD 2-BB-01-S405-4	9.195	300.327	-0.327	1.77E-08
53	WELD 2-BB-01-F407	9.635	300.222	-0.222	1.68E-08
54	WELD 2-EJ-04-S016-B	10.500	310.438	-10.438	0.00E+00(1)
55	WELD 2-EJ-04-S016-C	10.500	318.508	-18.508	0.00E+00(1)
56	WELD 2-EJ-04-S016-D	10.500	316.902	-16.902	0.00E+00(1)
57	WELD 2-EJ-04-S016-E	10.330	300.053	-0.053	3.78E-10
58	WELD 2-EJ-04-S016-G	9.485	300.239	-0.239	2.26E-09
59	WELD 2-EJ-04-S016-H	10.500	403.032	-103.032	0.00E+00(1)
60	WELD 2-EJ-04-F025	10.155	300.192	-0.192	7.67E-10
					5.37E-07

(1) When the interval collapses to a point (one break size), the exceedance frequency difference becomes identically equal to zero. The behavior described here is not an ad hoc or arbitrary interpretation of the NUREG-1829 exceedance frequency tables; it is a necessary attribute of the mathematical formalism.

Table 7-3 lists results for critical breaks identified using the continuum model where breaks of any size up to a full DEGB can occur on a weld. Under the continuum model, the search for a critical weld can be imagined as a systematic increase in break size on one weld beginning with a break of 0.1 inches in diameter and proceeding to larger breaks in 0.1 inch increments. Transported debris is compared to the RoverD test threshold at each step; if the transported debris exceeds the threshold, the location is judged to be a critical weld. The difference in exceedance frequency between the identified critical break size and the weld inner diameter (scaled by the number of welds in that size range) is assigned as the ΔCDF contribution. Clearly, if one D_i^{small} is found at a weld, then all larger breaks on that weld, up to the DEGB, are also capable of exceeding the RoverD threshold. Thus, the difference in exceedance frequency between D_i^{small} and the pipe inner diameter captures the full potential ΔCDF at each critical weld.

The assignment of exceedance frequency difference, defined over an interval of minimum to maximum break size, obeys a fundamental property of exceedance functions that include all complementary cumulative distribution functions used in PRA, Monte Carlo radiation transport codes, and numerous other applications in statistics, physics, engineering, and mathematics. The total annual LOCA frequency of all break sizes cannot be conserved mathematically by any means other than assignment of exceedance frequency differences defined over intervals of break size. One result of the exceedance frequency conservation property is that when the break size interval becomes very small, so does the corresponding assignment of annual break frequency that can occur within the interval. In fact, the exceedance frequency function has no meaning at a single break size, so when the interval collapses to a point (one break size), the exceedance frequency difference becomes identically equal to zero. The behavior described here is not an ad hoc or arbitrary interpretation of the NUREG-1829 exceedance frequency tables; it is a necessary attribute of the mathematical formalism.

During the critical weld search, there are often cases where none of the postulated hemispherical ZOI arising from breaks smaller than the pipe diameter can generate and transport more debris than the RoverD threshold, no matter how small the search increment may be. However, consistent with NEI-04-07 guidance, when the break size search becomes equal to the inner pipe diameter, a spherical ZOI is assumed that suddenly forms much more debris than the previous smaller break size that is assumed to have only a hemispherical ZOI; the RoverD threshold is exceeded by the spherical ZOI and the location is declared to be a critical weld for the special case of DEGB. The discrete jump to a spherical ZOI is an artifact of current guidance. Because all hemispherical breaks evaluated up to an arbitrarily small interval close to the pipe diameter have been found to pass the RoverD threshold, the residual interval containing the DEGB is vanishingly small, and the corresponding ΔCDF contribution of the DEGB becomes equal to zero.

Critical welds that are listed in Table 7-3 only because of their spherical ZOI DEGB failures are properly assigned zero ΔCDF contributions under the continuum break model. While it may be non-intuitive that the traditional “worst case” DEGB condition can have zero risk contribution, the conclusion is validated by two essential constraints: (1) every possible smaller break has been examined and found to be within the RoverD threshold, and (2) no breaks larger than the DEGB can form at a given weld. Because of the apparent contradiction with design-basis determinism, the NRC requested that the pilot plant also quantify ΔCDF for an alternate DEGB-only break model as a parametric study. The results for the DEGB-only break model for Callaway are presented in Section 9.1.

8 Secondary Risk Contributors

SRCs are evaluated to investigate the risk associated with initiators other than LOCA's at Class-I welds between the RPV and an isolation valve. SRCs include: (1) LOCA's at Class-I welds beyond the first isolation valve (i.e., isolable weld breaks concurrent with isolation valve failure); (2) LOCA's related to failedopen or spurious valve actuation; (3) pump seal LOCA's; and (4) secondary line breaks (concurrent with other failures that necessitate operation of the ECCS in sump recirculation mode). Refer to the responses to Questions 34 and 35 in Enclosure 5 for additional information regarding secondary risk contributor screening.

8.1 **Failure of Isolation Valves**

This section presents ∆CDF risk estimates for the failure of Class-I welds located both before and after the first isolation valve (refer to the response to Question 31 in Enclosure 5 for additional information regarding the definition of first isolation valves), consistent with failure of the isolation function of these valves. Class-I welds located beyond the first isolation valve are termed isolable welds, while Class-I welds located before the first isolation valve are termed non-isolable welds. Non-isolable welds are the welds examined in baseline evaluations; see Section 7. NUREG-1829 break frequencies strictly apply only to non-isolable welds, so including isolable welds in the total weld count dilute the frequency per weld. Therefore, isolable weld breaks are treated as a secondary risk contributor, independent of and in addition to risks associated with non-isolable weld breaks.

The analysis assumes that isolable welds on the outboard side of the valve are identical to non-isolable welds on the inboard side of the valve. This assumption is reasonable so long as the operating environment is similar on both sides of the valve. It follows from this assumption that NUREG-1829 frequencies per weld per year are independently applicable to breaks at isolable welds. Treating isolable welds as a separate population increases total break frequency above the NUREG-1829 top-down conservation limit, and is conservative in terms of total LOCA initiation frequency and total ∆CDF estimates.

A generic, conservative probability of failure for a valve's isolation function is 1.11E-03 (Reference [6]). Also refer to the response to Question 31 in Enclosure 5 for additional information regarding isolation valve failure probabilities. Therefore, individual isolable weld contributions to ∆CDF output by CASA Grande are multiplied by this factor to return the true per weld contributions to risk. The resulting values are then summed across all isolable welds and added to the total ∆CDF computed in the baseline scenario for non-isolable welds to yield the total ∆CDF across all isolable and non-isolable welds.

Table 8-1 provides ∆CDF estimates for the baseline scenario and for the isolation valve sensitivity. Both scenarios are based on the continuum break size model, geometric aggregation, and 25-year NUREG-1829 frequencies. Baseline ΔCDF estimates from Table 7-1 are reproduced (third row), along with the ΔCDF estimates for isolable welds both before (first row) and after (second row) multiplying by the isolation valve failure probability. Adding the values in the second and third rows provides ΔCDF estimates that include both isolable and non-isolable welds (last row). The results show isolable welds have negligible impact on ΔCDF. The 50-lbm fiber safety margin applied in the baseline scenario was also used in this sensitivity study.

Table 8-1: RoverD ΔCDF results considering isolable weld SRC

Scenario	**ΔCDF Statistic**			
	5th	**50th**	**Mean**	**95th**
Isolable Welds (Pre-Weighted)	1.09E-10	2.40E-09	1.13E-08	4.45E-08
Isolable Welds (Weighted)	1.22E-13	2.66E-12	1.25E-11	4.94E-11
Non-Isolable Welds (Baseline)	4.01E-09	9.04E-08	5.37E-07	1.95E-06
All Welds (Total)	4.01E-09	9.04E-08	5.37E-07	1.95E-06

Table 8-2 lists the critical isolable welds, or the welds that were found to transport an amount of LDFG debris that exceeds the 300-lbm limit derived from strainer testing. All critical isolable welds are large break LOCAs. Table 8-2 includes the critical break size to fail each critical isolable weld to within a resolution of 0.01 inches, the maximum quantity of LDFG debris transported at the critical break size, the fiber margin (the difference between the RoverD failure threshold and the amount of fiber transported), and the per weld contributions to ΔCDF (both before and after being weighted by the valve failure probability). Summing down the last column of the table returns the mean ΔCDF reported for the isolable weld scenario in Table 8-1. A table of debris transport results for DEGBs at all isolable welds in containment is provided in Table 10-4.

Table 8-2: Critical isolable welds for continuum break model and 25-year LOCA frequencies

#	**Weld Location Name**	**Smallest Break Size to Fail (inches)**	**Max Fiber Transported at Smallest Break Size (lbm)**	**Fiber Margin (lbm)**	**Contribution to GM ΔCDF (Unweighted)**	**Contribution to GM ΔCDF (Weighted)**
1	AFIVWELD 2-EJ-04-F032	9.525	300.186	-0.186	2.17E-09	2.41E-12
2	AFIVWELD 2-EJ-04-S019-D	10.285	300.556	-0.556	4.78E-10	5.30E-13
3	AFIVWELD 2-EJ-04-FW7	9.055	300.130	-0.130	3.21E-09	3.56E-12
4	AFIVWELD 2-EJ-04-S019-F	8.765	300.124	-0.124	3.86E-09	4.28E-12
5	AFIVWELD 2-EJ-04-F033	10.500	410.195	-110.195	0.00E+00	0.00E+00
6	AFIVWELD 2-EJ-04-S015-E	10.500	372.189	-72.189	0.00E+00	0.00E+00
7	AFIVWELD 2-EJ-04-F024	9.795	300.001	-0.001	1.57E-09	1.74E-12
					1.13E-08	**1.25E-11**

8.2 **Secondary Line Breaks**

Secondary line breaks (large main steam and feedwater line breaks) are considered as secondary risk contributors. Refer to the responses to Questions 34 and 35 in Enclosure 5 for additional information regarding secondary risk contributor screening. Based on the screening results, there is no contribution to ΔCDF/LERF associated with GL 2004-02 phenomena from secondary line breaks.

8.3 **Spurious and Failed-Open Relief and Safety Valves**

Spurious actuation and failed-open primary system relief and safety valves are considered as secondary risk contributors. In accordance with the pilot-plant submittal, relief and safety valve actuation is very similar to a small LOCA in thermodynamic response, and the smallest critical break size for Callaway is 9.145 inches (a large break). Because small or medium breaks do not lead to core damage due to GL 2004-02 phenomena, there is no significant contribution to ΔCDF from spurious actuation and failed-open relief and safety valves. This conclusion is further supported by the observation that relief and safety valves discharge into regions with minimal to no insulated process piping. Refer to the responses to Questions 34 and 35 in Enclosure 5 for additional information regarding secondary risk contributor screening.

8.4 **Mechanical LOCA (Pump Seal LOCA)**

Mechanical LOCAs (pump seal LOCAs) are considered as secondary risk contributors. In accordance with the pilot plant submittal, mechanical LOCAs would be very similar to a small LOCA in thermodynamic response, and the smallest critical break size for Callaway is 9.145 inches (a large break). Because small or medium breaks do not lead to core damage due to GL 2004-02 phenomena, there is no contribution to ΔCDF from mechanical LOCAs. This conclusion is further supported by the observation that thermally insulated Reactor Coolant Pumps (RCP) are co-located with heavily insulated pipes in steam generator compartments that are examined extensively in all CASA debris generation calculations. Therefore, there is no possibility that RCP seal LOCA can generate an unexpectedly large amount of debris that could challenge ECCS strainers.

8.5 **Additional Secondary Risk Contributors**

Additional secondary risk contributors, including ex-vessel downstream wear, strainer structural analysis, as well as in-vessel effects, which are analyzed with current WCAP-17788 methods, do not result in any failures and do not increase incremental risk of core damage.

The Callaway seismic PRA identifies several seismic-induced large loss of coolant accident (LLOCA) breaks that lead to core damage, so seismic-induced risk for these events is explicitly quantified in the PRA. All seismically-induced LLOCA events, with the exception of one, are assumed to go directly to core damage, therefore, core damage due to GL 2004-02 phenomena is encompassed for these seismic events. The seismic PRA identifies one seismic-induced LLOCA, on the Pressurizer Surge Line, that does not proceed directly to core damage. However, no pressurizer surge line welds appear in the list of critical welds (Table 9.3), so debris generated by this seismically induced LLOCA does not exceed the deterministic capacity of the strainers and the event does not contribute incremental risk to the RoverD analysis.

During long-term cooling, the potential exists for boiling in the core to cause boric acid concentration to build up to a level where precipitation of boron from solution occurs. Plate-out of boron precipitate on fuel rods could reduce heat transfer and restrict the flow of cooling water, resulting in cladding heat up. The Callaway Accident Analysis Basis Document (AABD) confirms that CL, HL, and simultaneous CL/HL minimum injection flow rates are sufficient to prevent buildup of boric acid in the core and to dilute a high concentration in the core region, if one exists, prior to reaching the boric acid solubility limit, and that the 13-hour HLSO time addresses the boric acid precipitation concern.

Refer to the responses to Questions 34 and 35 in Enclosure 5 for additional information regarding secondary risk contributor screening.

9 Sensitivities

This section presents results for sensitivity studies performed to assess relative changes to RoverD ∆CDF risk from the baseline scenario given changes to input parameters and model assumptions. These sensitivities aim to interpret or apply regulatory guidance and industry knowledge in a different manner than the baseline, consistent with sensitivity evaluations performed by the pilot plant. Two types of sensitivity studies are performed for this analysis. One set of sensitivities explores the effects of using alternative initiating event frequencies and an alternative break model, and another sensitivity study explores the effect of adding additional insulation at valve locations.

Section 9.1 provides a discussion and results for sensitivity studies that use alternative initiating event frequencies and break size models. These studies include:

1. Using a DEGB-only break model instead of the continuum break model. For this sensitivity, the only breaks that can occur in the plant are DEGBs. Partial pipe breaks are not permitted to occur.
2. Using 40-year LOCA frequencies instead of 25-year LOCA frequencies. Both sets of frequencies are provided in NUREG-1829, but the 40-year frequencies are higher with wider uncertainties to account for extended plant life.

3. Using arithmetic aggregation (arithmetic means) for the initiating event frequencies instead of geometric aggregation (geometric means). The frequency data reported in NUREG-1829 were elicited from individual experts and then aggregated to provide a standard set of frequencies across all experts. Geometric aggregation is generally deemed the most appropriate aggregation method for this application, because it reduces the effect of outliers. Arithmetic aggregation weights all elicited values equally and is explored as a sensitivity for possible change in methodology. Refer to the response to Question 36 in Enclosure 5 for additional information regarding sensitivity analysis.

These parameter sensitivities do not affect debris destruction or transport, and so they do not influence critical welds or break sizes. Because of this simplicity, only the corresponding risk (ΔCDF) estimates are presented for these sensitivities. Note that the 50-lbm fiber safety margin used in the baseline scenario was also used in these sensitivity studies.

Section 9.2 provides a discussion and results for a valve insulation sensitivity that applies additional insulation to select valves in containment, where more insulation may be present to conform to valve geometry, beyond the amount of insulation already applied to valve bodies in the baseline calculation. This sensitivity evaluates whether extra insulation at valve locations either causes any baseline non-critical weld to become a critical weld, or reduces the critical break size for any of the present baseline critical welds. Because this sensitivity study introduces additional LDFG debris at valve locations with the potential for destruction, an updated critical weld list is provided for the sensitivity in addition to the revised risk (ΔCDF) estimates.

9.1 Initiating Event Frequency and Break Size Model Sensitivities

This section summarizes risk results for the sensitivity studies designed to assess the effect that alternative initiating frequency aggregation methods (geometric vs. arithmetic means), break size models (continuum vs. DEGB-only), and initiating event frequency plant life (25-year vs. 40-year) have on ΔCDF estimates for Callaway. Table 9-1 contains a summary of ΔCDF results for each parameter sensitivity evaluated, where the first row reproduces the baseline results presented in Table 7-1.

Table 9-1: RoverD ΔCDF results for LOCA frequency sensitivity scenarios

#	Plant Life	Aggregation Model	Break Model	ΔCDF Statistic 5th	50th	Mean	95th
0	25-Year	Geometric	Continuum	4.01E-09	9.04E-08	5.37E-07	1.95E-06
1	25-Year	Geometric	DEGB	5.52E-09	1.23E-07	6.70E-07	2.51E-06
2	25-Year	Arithmetic	Continuum	2.50E-08	5.14E-07	4.07E-06	1.29E-05
3	25-Year	Arithmetic	DEGB	3.11E-08	6.16E-07	4.73E-06	1.52E-05
4	40-Year	Geometric	Continuum	8.12E-09	1.94E-07	1.22E-06	4.52E-06
5	40-Year	Geometric	DEGB	1.11E-08	2.62E-07	1.52E-06	5.78E-06
6	40-Year	Arithmetic	Continuum	3.54E-08	7.38E-07	8.08E-06	2.46E-05
7	40-Year	Arithmetic	DEGB	4.40E-08	9.00E-07	9.69E-06	3.06E-05

To illustrate the distribution of RoverD ΔCDF estimates considering the full range of uncertainty, all quantiles of the continuum and DEGB-only risk calculations are plotted in Figure 7-1 (and reproduced in Figure 9-1) based on geometric aggregation of the 25-year NUREG-1829 frequencies. Continuous interpolated quantile values were derived from Bounded Johnson distributions fit to NUREG-1829 data. Considering the full range of uncertainty, approximately 88% of postulated LOCA scenarios place ΔCDF risk in Region III of Regulatory Guide 1.174 (Reference [1]) for the continuum model, while approximately 85% fall into Region III for the DEGB-only model. Figure 9-2 compares the same ΔCDF risk distributions based on arithmetic aggregation of the NUREG-1829 LOCA frequencies.

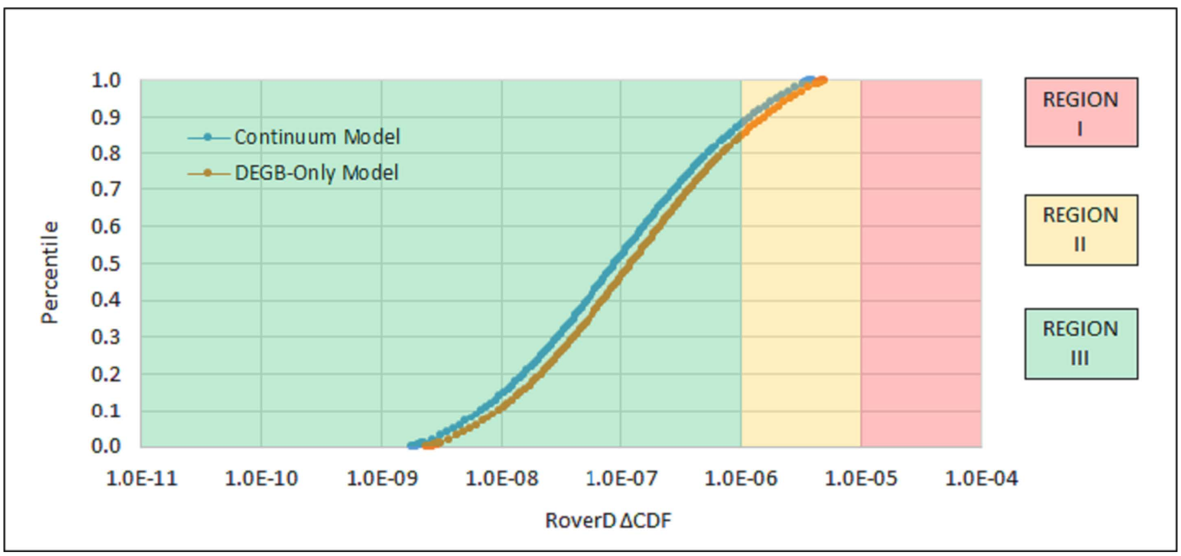


Figure 9-1: Distributions of RoverD ΔCDF for 25-year geometric mean LOCA exceedance frequencies

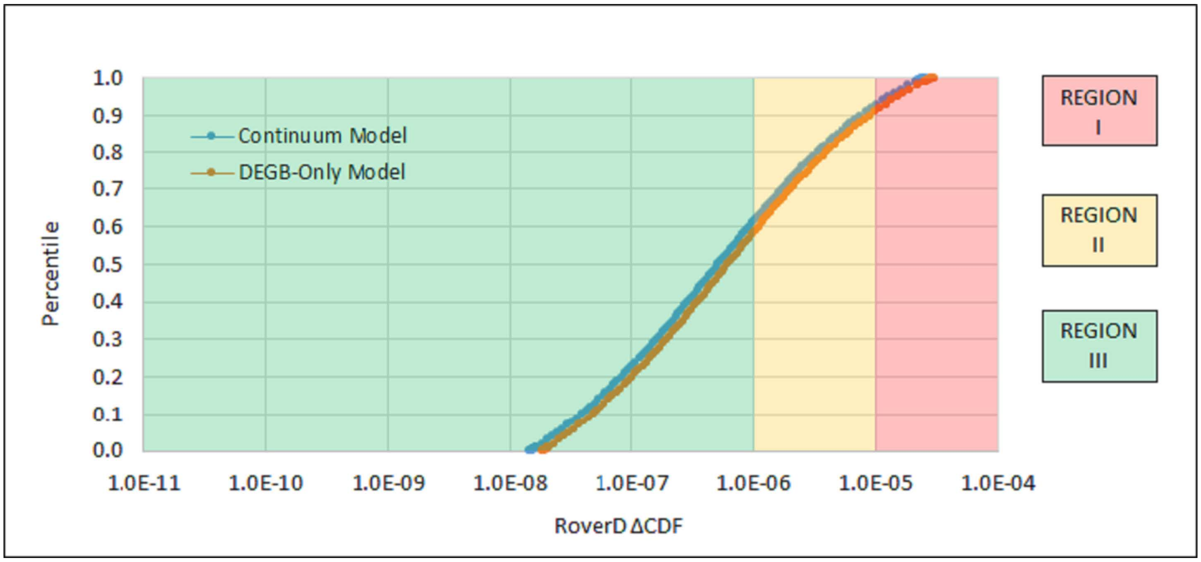


Figure 9-2: Distributions of RoverD ΔCDF for 25-year arithmetic mean LOCA exceedance frequencies

9.2 Valve Insulation Sensitivity Study

The valve insulation sensitivity scenario applies additional insulation to valves in containment, where more insulation may be present to conform to valve geometry, beyond the valve insulation already applied in the baseline calculation. Extra LDFG insulation is applied to valves on select pipe sizes based on valve sizes defined in the CASA Grande input deck. Additional valve insulation has the potential to cause non-critical welds to become critical welds and to reduce critical break sizes for critical welds, both of which would increase ΔCDF. This sensitivity determines whether increasing LDFG insulation around valves has a significant impact on ΔCDF estimates. Additional insulation was added to all valve bodies by adding collars of insulation at the valves where the collars have the same thickness as the insulation already present, effectively doubling the insulation at valve locations for the length of the collar (where the length of the collar is a function of the pipe diameters). Note that the 50-lbm fiber safety margin used in the baseline scenario was also used in this sensitivity study.

A summary of ΔCDF results for the valve insulation sensitivity is provided in Table 9-2. These results are based on the continuum break model and geometric aggregation of the 25-year LOCA frequencies elicited in NUREG-1829. Table 9-2 shows that the mean ΔCDF for RoverD fiber debris increases approximately 0.56% above the baseline risk of 5.37E-07 as a result of the extra valve insulation.

Table 9-2: RoverD ΔCDF results for valve insulation sensitivity

Statistic	5th	50th	Mean	95th
ΔCDF	4.05E-09	9.10E-08	5.40E-07	1.97E-06

Table 9-3 lists Class-I welds located between the RPV and the first isolation valve that were found to transport LDFG debris in excess of the tested 300-lbm RoverD fiber failure threshold for the valve insulation sensitivity scenario. Table 9-3 includes the critical break size for each critical weld determined to a resolution of 0.01 inches, the maximum quantity of LDFG debris transported at the critical break size, the fiber margin (the difference between the RoverD fiber failure threshold and the amount of fiber transported), and the per weld contribution to ΔCDF. Note that summing the last column of the table returns the mean ΔCDF reported in Table 9-2. Careful comparison of Table 9-3 for the valve insulation sensitivity and Table 7-3 for the baseline conditions reveals that no new critical welds are added because of the extra insulation, but critical break sizes do decrease slightly for some baseline critical welds. A table of results for DEGBs at all welds in containment is provided in Table 10-2.

Table 9-3: Critical weld list for valve insulation sensitivity scenario

#	Weld Location Name	Smallest Break Size to Fail (inches)	Max Fiber Transported at Smallest Break Size (lbm)	Fiber Margin (lbm)	Per Weld Contribution to ΔCDF
1	WELD EBB01B-RSG-OUTLET-SC010	11.855	300.091	-0.091	1.09E-08
2	WELD 2-BB-01-3065B-WDC-002-FW2	11.795	300.354	-0.354	1.11E-08
3	WELD 2-BB-01-F206	11.495	300.096	-0.096	1.20E-08
4	WELD 2-BB-01-S204-3	11.885	300.149	-0.149	1.08E-08
5	WELD 2-BB-01-F208	11.535	300.442	-0.442	1.19E-08
6	WELD 2-BB-01-S205-4	10.975	300.186	-0.186	1.36E-08
7	WELD 2-BB-01-F207	11.525	300.048	-0.048	1.19E-08
8	WELD 2-BB-01-S201-2	27.500	317.064	-17.064	0.00E+00
9	WELD 2-BB-01-F201	10.775	300.336	-0.336	1.20E-08
10	WELD 2-BB-01-S202-2	13.275	300.395	-0.395	4.70E-09
11	WELD 2-BB-01-3065B-WDC-001-FW1	13.225	300.217	-0.217	4.86E-09
12	WELD EBB01B-RSG-INLET-SC010	13.255	300.190	-0.190	4.76E-09
13	WELD 2-EJ-04-FW9	10.500	328.112	-28.112	0.00E+00
14	WELD 2-EJ-04-S018-C	10.500	329.742	-29.742	0.00E+00
15	WELD 2-EJ-04-FW8	10.500	327.464	-27.464	0.00E+00
16	WELD 2-EJ-04-S018-E	10.500	351.483	-51.483	0.00E+00
17	WELD 2-EJ-04-F031	9.975	300.031	-0.031	1.17E-09
18	WELD EBB01A-RSG-OUTLET-SC010	10.905	300.032	-0.032	1.37E-08
19	WELD 2-BB-01-3065A-WDC-002-FW2	10.805	300.247	-0.247	1.40E-08
20	WELD 2-BB-01-F106	9.965	300.022	-0.022	1.60E-08
21	WELD 2-BB-01-S104-3	9.915	300.010	-0.010	1.61E-08
22	WELD 2-BB-01-F108	9.915	300.054	-0.054	1.61E-08
23	WELD 2-BB-01-S105-4	9.125	300.446	-0.446	1.79E-08
24	WELD 2-BB-01-F107	9.595	300.226	-0.226	1.68E-08
25	WELD 2-BB-01-S102-2	11.755	300.411	-0.411	9.45E-09
26	WELD 2-BB-01-3065A-WDC-001-FW1	11.525	300.508	-0.508	1.02E-08
27	WELD EBB01A-RSG-INLET-SC010	11.565	300.063	-0.063	1.00E-08

#	Weld Location Name	Smallest Break Size to Fail (inches)	Max Fiber Transported at Smallest Break Size (lbm)	Fiber Margin (lbm)	Per Weld Contribution to ∆CDF
28	WELD 2-RV-302-121-A	26.965	300.010	-0.010	8.41E-11
29	WELD 2-BB-01-F102	26.635	300.051	-0.051	1.36E-10
30	WELD 2-BB-01-S101-2	27.500	348.521	-48.521	0.00E+00
31	WELD 2-BB-01-F101	9.435	300.061	-0.061	1.51E-08
32	WELD EBB01C-RSG-OUTLET-SC010	11.575	300.355	-0.355	1.18E-08
33	WELD 2-BB-01-3065C-WDC-002-FW2	11.475	300.203	-0.203	1.21E-08
34	WELD 2-BB-01-F306	10.915	300.239	-0.239	1.37E-08
35	WELD 2-BB-01-S304-3	11.265	300.662	-0.662	1.27E-08
36	WELD 2-BB-01-F308	11.195	300.684	-0.684	1.30E-08
37	WELD 2-BB-01-S305-4	10.465	300.010	-0.010	1.49E-08
38	WELD 2-BB-01-F307	11.105	300.219	-0.219	1.32E-08
39	WELD 2-BB-01-F301	11.285	300.220	-0.220	1.06E-08
40	WELD 2-BB-01-S302-2	13.395	300.187	-0.187	4.33E-09
41	WELD 2-BB-01-3065C-WDC-001-FW1	12.955	300.174	-0.174	5.70E-09
42	WELD EBB01C-RSG-INLET-SC010	12.955	300.059	-0.059	5.70E-09
43	WELD 2-BB-01-S402-2	12.365	300.024	-0.024	7.55E-09
44	WELD 2-BB-01-3065D-WDC-001-FW1	11.815	300.104	-0.104	9.26E-09
45	WELD EBB01D-RSG-INLET-SC010	11.855	300.059	-0.059	9.14E-09
46	WELD 2-BB-01-F401	9.875	300.026	-0.026	1.42E-08
47	WELD EBB01D-RSG-OUTLET-SC010	10.735	300.381	-0.381	1.42E-08
48	WELD 2-BB-01-3065D-WDC-002-FW2	10.635	300.582	-0.582	1.45E-08
49	WELD 2-BB-01-F406	9.835	300.246	-0.246	1.63E-08
50	WELD 2-BB-01-S404-3	9.685	300.416	-0.416	1.66E-08
51	WELD 2-BB-01-F408	9.585	300.101	-0.101	1.69E-08
52	WELD 2-BB-01-S405-4	9.175	300.111	-0.111	1.78E-08
53	WELD 2-BB-01-F407	9.605	300.161	-0.161	1.68E-08
54	WELD 2-EJ-04-S016-B	10.500	311.199	-11.199	0.00E+00
55	WELD 2-EJ-04-S016-C	10.500	319.269	-19.269	0.00E+00
56	WELD 2-EJ-04-S016-D	10.500	317.662	-17.662	0.00E+00
57	WELD 2-EJ-04-S016-E	10.330	300.053	-0.053	3.78E-10
58	WELD 2-EJ-04-S016-G	9.485	300.287	-0.287	2.26E-09
59	WELD 2-EJ-04-S016-H	10.500	403.966	-103.966	0.00E+00
60	WELD 2-EJ-04-F025	10.135	300.624	-0.624	8.11E-10
					5.40E-07

10 Full Weld Lists

This section presents tabulated results for all RoverD simulations presented in the previous sections. These results include transported debris quantities and risk contributions postulated at all welds in containment.

10.1 **Full Weld List for Baseline Scenario**

This section contains a full weld list for the baseline analysis scenario. Table 10-1 lists the weld location name, the corresponding pipe diameter (DEGB size), the amount of fiber transported by a DEGB, the fiber margin (the difference between the RoverD failure threshold and the amount of fiber transported), and the contribution of each weld to the geometric mean ΔCDF based on 25-year NUREG-1829 frequencies at the smallest critical break size. Welds that do not exceed the RoverD limit for a DEGB are deemed non-critical welds. Non-critical welds have a positive fiber margin and do not contribute to ΔCDF. Note that per weld contributions to ΔCDF in the last column sum to the mean ΔCDF reported for the baseline scenario reported in Table 7-1 and Table 9-1.

Table 10-1: Full weld list for baseline scenario

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ΔCDF
1	WELD 2-BB-04-F005	3.440	94.968	205.032	0.00E+00
2	WELD 2-BB-04-S003-D	3.440	96.138	203.862	0.00E+00
3	WELD 2-BB-04-S003-C	3.440	96.907	203.093	0.00E+00
4	WELD 2-BB-04-F006	3.440	103.704	196.296	0.00E+00
5	WELD 2-BB-04-S004-C	3.440	107.348	192.652	0.00E+00
6	WELD 2-BB-04-F007	3.440	105.538	194.462	0.00E+00
7	WELD 2-BB-04-S005-D	3.440	106.904	193.096	0.00E+00
8	WELD 2-BB-04-S005-C	3.440	105.307	194.693	0.00E+00
9	WELD 2-BB-04-S005-B	3.440	98.012	201.988	0.00E+00
10	WELD 2-BB-04-F008	3.440	98.011	201.989	0.00E+00
11	WELD 2-BB-04-S006-C	3.440	93.206	206.794	0.00E+00
12	WELD 2-BB-04-S006-B	3.440	91.505	208.495	0.00E+00
13	WELD 2-BB-04-F009	3.440	87.065	212.935	0.00E+00
14	WELD 2-BB-04-S007-F	3.440	87.235	212.765	0.00E+00
15	WELD 2-BB-04-S007-E	3.440	88.794	211.206	0.00E+00
16	WELD 2-BB-04-S007-D	3.440	88.661	211.339	0.00E+00
17	WELD 2-BB-04-S007-B	3.440	88.421	211.579	0.00E+00
18	WELD 2-BB-04-F010	3.440	88.433	211.567	0.00E+00
19	WELD 2-BB-04-S008-D	3.440	88.422	211.578	0.00E+00
20	WELD 2-BB-04-S008-C	3.440	88.403	211.597	0.00E+00
21	WELD 2-BB-04-S008-B	3.440	88.671	211.329	0.00E+00
22	WELD 2-BB-04-F011	3.440	88.159	211.841	0.00E+00
23	WELD 2-BB-04-S009-D	3.440	106.447	193.553	0.00E+00
24	WELD 2-BB-04-S009-C	3.440	108.635	191.365	0.00E+00
25	WELD 2-BB-04-S009-B	3.440	116.486	183.514	0.00E+00
26	WELD 2-BB-04-F012	3.440	119.125	180.875	0.00E+00
27	WELD 2-BB-01-S101-5	3.440	123.402	176.598	0.00E+00
28	WELD 2-BB-04-F015	3.440	91.238	208.762	0.00E+00
29	WELD 2-BB-04-S012-F	3.440	90.168	209.832	0.00E+00
30	WELD 2-BB-04-S012-E	3.440	90.688	209.312	0.00E+00
31	WELD 2-BB-04-S012-D	3.440	93.768	206.232	0.00E+00
32	WELD 2-BB-04-S012-C	3.440	93.125	206.875	0.00E+00
33	WELD 2-BB-04-F016	3.440	96.859	203.141	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
34	WELD 2-BB-04-S013-F	3.440	99.468	200.532	0.00E+00
35	WELD 2-BB-04-S013-H	3.440	98.851	201.149	0.00E+00
36	WELD 2-BB-04-S013-D	3.440	101.795	198.205	0.00E+00
37	WELD 2-BB-04-S013-C	3.440	102.798	197.202	0.00E+00
38	WELD 2-BB-04-S013-B	3.440	102.469	197.531	0.00E+00
39	WELD 2-BB-04-F017	3.440	102.978	197.022	0.00E+00
40	WELD 2-BB-04-S014-E	3.440	89.674	210.326	0.00E+00
41	WELD 2-BB-04-S014-D	3.440	88.802	211.198	0.00E+00
42	WELD 2-BB-04-S014-C	3.440	88.277	211.723	0.00E+00
43	WELD 2-BB-04-S014-B	3.440	88.390	211.610	0.00E+00
44	WELD 2-BB-04-F018	3.440	91.391	208.609	0.00E+00
45	WELD 2-BB-04-S015-F	3.440	91.404	208.596	0.00E+00
46	WELD 2-BB-04-S015-E	3.440	88.741	211.259	0.00E+00
47	WELD 2-BB-04-S015-D	3.440	88.717	211.283	0.00E+00
48	WELD 2-BB-04-S015-B	3.440	88.429	211.571	0.00E+00
49	WELD 2-BB-04-F019	3.440	88.425	211.575	0.00E+00
50	WELD 2-BB-04-FW2	3.440	88.383	211.617	0.00E+00
51	WELD 2-BB-04-S016-C	3.440	88.354	211.646	0.00E+00
52	WELD 2-BB-04-S016-B	3.440	84.471	215.529	0.00E+00
53	WELD 2-BB-04-F020	3.440	84.712	215.288	0.00E+00
54	WELD 2-BB-04-S017-B	3.440	85.368	214.632	0.00E+00
55	WELD 2-BB-04-F021	3.440	85.865	214.135	0.00E+00
56	WELD 2-BB-04-S018-D	3.440	114.235	185.765	0.00E+00
57	WELD 2-BB-04-S018-C	3.440	114.904	185.096	0.00E+00
58	WELD 2-BB-04-S018-B	3.440	117.401	182.599	0.00E+00
59	WELD 2-BB-04-F022	3.440	120.151	179.849	0.00E+00
60	WELD 2-EM-03-BBV059-2	1.340	81.266	218.734	0.00E+00
61	WELD 2-EM-03-FW225	1.340	81.174	218.826	0.00E+00
62	WELD 2-EM-03-FW226	1.340	80.281	219.719	0.00E+00
63	WELD 2-EM-03-FW227	1.340	83.183	216.817	0.00E+00
64	WELD 2-BB-01-S401-6	2.630	108.123	191.877	0.00E+00
65	WELD 2-BB-01-S401-10	2.630	107.102	192.898	0.00E+00
66	WELD 2-EM-03-FW259	1.340	83.669	216.331	0.00E+00
67	WELD 2-EM-03-FW258	1.340	80.368	219.632	0.00E+00
68	WELD 2-EM-03-BBV040-2	1.340	80.366	219.634	0.00E+00
69	WELD 2-BB-01-S301-5	2.630	112.110	187.890	0.00E+00
70	WELD 2-BB-01-S301-9	2.630	110.029	189.971	0.00E+00
71	WELD 2-HB-24-FW67	1.690	87.849	212.151	0.00E+00
72	WELD 2-HB-24-FW66	1.690	86.476	213.524	0.00E+00
73	WELD 2-HB-24-FW065	1.690	85.407	214.593	0.00E+00
74	WELD 2-HB-24-FW064	1.690	82.426	217.574	0.00E+00
75	WELD 2-BB-01-F004	11.190	173.660	126.340	0.00E+00
76	WELD 2-TBB03-1-W	11.190	173.660	126.340	0.00E+00
77	WELD 2-BB-01-S003-3	11.190	181.889	118.111	0.00E+00
78	WELD 2-BB-01-S003-2	11.190	200.906	99.094	0.00E+00
79	WELD 2-BB-01-S003-8	11.190	244.412	55.588	0.00E+00
80	WELD 2-BB-01-F003	11.190	187.063	112.937	0.00E+00
81	WELD 2-BB-01-F002	11.190	206.374	93.626	0.00E+00
82	WELD 2-BB-01-S001-6	11.190	191.730	108.270	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
83	WELD 2-BB-01-F001	11.190	283.298	16.702	0.00E+00
84	WELD 2-BB-01-S101-8	2.630	109.163	190.837	0.00E+00
85	WELD 2-BG-21-F014	2.630	106.172	193.828	0.00E+00
86	WELD 2-BG-21-FW-1	2.630	94.047	205.953	0.00E+00
87	WELD 2-BG-21-S010-D	2.630	87.327	212.673	0.00E+00
88	WELD 2-BG-21-S010-C	2.630	85.603	214.397	0.00E+00
89	WELD 2-BG-21-S010-B	2.630	86.262	213.738	0.00E+00
90	WELD 2-BG-21-S010-A	2.630	86.093	213.907	0.00E+00
91	WELD 2-BG-21-F013	2.630	84.796	215.204	0.00E+00
92	WELD 2-EP-02-F008	8.750	262.269	37.731	0.00E+00
93	WELD 2-EP-02-S004-E	8.750	259.170	40.830	0.00E+00
94	WELD 2-EP-02-FW2	8.750	249.745	50.255	0.00E+00
95	WELD 2-EP-02-S004-C	8.750	232.063	67.937	0.00E+00
96	WELD 2-EP-02-F007	8.750	230.776	69.224	0.00E+00
97	WELD 2-EM-03-F012	5.190	128.111	171.889	0.00E+00
98	WELD 2-EM-03-S012-D	5.190	126.707	173.293	0.00E+00
99	WELD 2-EM-03-S012-B	5.190	123.221	176.779	0.00E+00
100	WELD 2-EM-03-W237498-FW03	5.190	122.294	177.706	0.00E+00
101	WELD 2-BB-11-C600739-FW01	1.340	79.817	220.183	0.00E+00
102	WELD 2-BB-11-A600739B-FW01	1.340	79.429	220.571	0.00E+00
103	WELD 2-BB-11-FW008	1.690	78.800	221.200	0.00E+00
104	WELD 2-BB-11-FW011	1.690	78.800	221.200	0.00E+00
105	WELD 2-BB-11-FW012	1.690	78.800	221.200	0.00E+00
106	WELD 2-BB-11-FW013	1.690	78.800	221.200	0.00E+00
107	WELD 2-BB-11-FW014	1.690	80.321	219.679	0.00E+00
108	WELD 2-BB-11-FW015	1.690	80.019	219.981	0.00E+00
109	WELD 2-BB-11-FW016	1.690	79.903	220.097	0.00E+00
110	WELD 2-BB-11-V151-2	1.690	79.801	220.199	0.00E+00
111	WELD 2-EM-03-FW269	1.340	83.233	216.767	0.00E+00
112	WELD 2-EM-03-FW268	1.340	81.483	218.517	0.00E+00
113	WELD 2-EM-03-BBV022-2	1.340	81.313	218.687	0.00E+00
114	WELD 2-BB-01-S201-8	2.630	99.038	200.962	0.00E+00
115	WELD 2-BB-01-S201-15	2.630	98.619	201.381	0.00E+00
116	WELD 2-BB-06-F006	2.630	98.006	201.994	0.00E+00
117	WELD 2-BB-06-F001	2.630	101.122	198.878	0.00E+00
118	WELD 2-BB-01-S205-5	2.630	102.665	197.335	0.00E+00
119	WELD 2-BB-01-S205-6	1.690	88.213	211.787	0.00E+00
120	WELD EBB01B-RSG-OUTLET-SC010	31.000	1099.195	-799.195	1.09E-08
121	WELD 2-BB-01-3065B-WDC-002-FW2	31.000	1096.277	-796.277	1.11E-08
122	WELD 2-BB-01-F206	31.000	1081.797	-781.797	1.20E-08
123	WELD 2-BB-01-S204-3	31.000	1065.208	-765.208	1.08E-08
124	WELD 2-BB-01-F208	31.000	981.925	-681.925	1.18E-08
125	WELD 2-BB-01-S205-4	31.000	980.793	-680.793	1.31E-08
126	WELD 2-BB-01-F207	31.000	985.974	-685.974	1.19E-08
127	WELD 2-BB-01-S201-7	8.750	266.859	33.141	0.00E+00
128	WELD 2-BB-01-S201-3	1.690	89.972	210.028	0.00E+00
129	WELD 2-BB-01-S201-4	2.120	97.072	202.928	0.00E+00
130	WELD 2-BB-01-S201-5	3.440	124.006	175.994	0.00E+00
131	WELD 2-RV-302-121-B	27.500	283.530	16.470	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
132	WELD 2-BB-01-F202	27.500	286.476	13.524	0.00E+00
133	WELD 2-BB-01-S201-2	27.500	313.423	-13.423	0.00E+00
134	WELD 2-BB-01-F201	27.500	930.743	-630.743	1.18E-08
135	WELD 2-BB-01-S202-3	5.190	130.149	169.851	0.00E+00
136	WELD 2-RV-301-121-B	29.000	272.120	27.880	0.00E+00
137	WELD 2-BB-01-F203	29.000	197.316	102.684	0.00E+00
138	WELD 2-BB-01-S202-2	29.000	1102.716	-802.716	4.70E-09
139	WELD 2-BB-01-3065B-WDC-001-FW1	29.000	1112.346	-812.346	4.86E-09
140	WELD EBB01B-RSG-INLET-SC010	29.000	1110.187	-810.187	4.76E-09
141	WELD 2-EM-03-FW235	1.340	83.374	216.626	0.00E+00
142	WELD 2-EM-03-FW234	1.340	81.061	218.939	0.00E+00
143	WELD 2-EM-03-BBV001-2	1.340	81.005	218.995	0.00E+00
144	WELD 2-BB-01-S101-9	2.630	100.782	199.218	0.00E+00
145	WELD 2-BB-01-S101-13	2.630	99.992	200.008	0.00E+00
146	WELD 2-EJ-04-F030	10.500	297.911	2.089	0.00E+00
147	WELD 2-EJ-04-FW9	10.500	327.631	-27.631	0.00E+00
148	WELD 2-EJ-04-S018-C	10.500	329.261	-29.261	0.00E+00
149	WELD 2-EJ-04-FW8	10.500	326.983	-26.983	0.00E+00
150	WELD 2-EJ-04-S018-E	10.500	351.002	-51.002	0.00E+00
151	WELD 2-EJ-04-F031	10.500	407.705	-107.705	1.14E-09
152	WELD 2-BB-08-FW041-A-R-1	1.690	79.052	220.948	0.00E+00
153	WELD 2-BB-08-FW099	1.690	79.021	220.979	0.00E+00
154	WELD 2-BB-08-FW044	1.690	78.910	221.090	0.00E+00
155	WELD 2-BB-08-FW045	1.690	78.800	221.200	0.00E+00
156	WELD 2-BB-08-FW046-A	1.690	78.800	221.200	0.00E+00
157	WELD 2-BB-08-FW047	1.690	78.800	221.200	0.00E+00
158	WELD 2-BB-08-FW052-B	1.690	78.800	221.200	0.00E+00
159	WELD 2-BB-08-FW053	1.690	78.800	221.200	0.00E+00
160	WELD 2-BB-08-V121-2	1.690	78.800	221.200	0.00E+00
161	WELD 2-BB-08-FW039	1.340	79.883	220.117	0.00E+00
162	WELD 2-BB-08-FW040	1.340	78.800	221.200	0.00E+00
163	WELD 2-BB-05-F006	2.630	110.123	189.877	0.00E+00
164	WELD 2-BB-05-F001	2.630	111.485	188.515	0.00E+00
165	WELD 2-BB-01-S105-5	2.630	111.691	188.309	0.00E+00
166	WELD 2-BB-01-S105-6	1.690	88.356	211.644	0.00E+00
167	WELD EBB01A-RSG-OUTLET-SC010	31.000	1125.091	-825.091	1.37E-08
168	WELD 2-BB-01-3065A-WDC-002-FW2	31.000	1123.163	-823.163	1.40E-08
169	WELD 2-BB-01-F106	31.000	1106.701	-806.701	1.60E-08
170	WELD 2-BB-01-S104-3	31.000	1090.089	-790.089	1.61E-08
171	WELD 2-BB-01-F108	31.000	1025.453	-725.453	1.61E-08
172	WELD 2-BB-01-S105-4	31.000	1032.738	-732.738	1.78E-08
173	WELD 2-BB-01-F107	31.000	1027.755	-727.755	1.68E-08
174	WELD 2-BB-01-S102-3	10.500	285.100	14.900	0.00E+00
175	WELD 2-RV-301-121-A	29.000	291.665	8.335	0.00E+00
176	WELD 2-BB-01-F103	29.000	201.121	98.879	0.00E+00
177	WELD 2-BB-01-S102-2	29.000	1141.289	-841.289	9.45E-09
178	WELD 2-BB-01-3065A-WDC-001-FW1	29.000	1143.669	-843.669	1.02E-08
179	WELD EBB01A-RSG-INLET-SC010	29.000	1141.237	-841.237	1.00E-08
180	WELD 2-BB-01-S101-7	8.750	298.102	1.898	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
181	WELD 2-BB-01-S101-3	1.690	89.457	210.543	0.00E+00
182	WELD 2-RV-302-121-A	27.500	302.456	-2.456	2.75E-11
183	WELD 2-BB-01-F102	27.500	306.069	-6.069	8.25E-11
184	WELD 2-BB-01-S101-2	27.500	345.081	-45.081	0.00E+00
185	WELD 2-BB-01-F101	27.500	983.684	-683.684	1.50E-08
186	WELD 2-HB-24-FW001	1.690	88.017	211.983	0.00E+00
187	WELD 2-HB-24-FW002	1.690	86.761	213.239	0.00E+00
188	WELD 2-HB-24-FW078	1.690	85.640	214.360	0.00E+00
189	WELD 2-HB-24-FW079-A	1.690	80.963	219.037	0.00E+00
190	WELD 2-EP-01-F008	8.750	273.860	26.140	0.00E+00
191	WELD 2-EP-01-S004-E	8.750	268.120	31.880	0.00E+00
192	WELD 2-EP-01-S004-D	8.750	254.212	45.788	0.00E+00
193	WELD 2-EP-01-S004-C	8.750	235.325	64.675	0.00E+00
194	WELD 2-EP-01-F007	8.750	233.631	66.369	0.00E+00
195	WELD 2-EJ-04-S018-F	5.190	125.978	174.022	0.00E+00
196	WELD 2-EM-05-F007	5.190	123.837	176.163	0.00E+00
197	WELD 2-EM-05-S007-D	5.190	123.095	176.905	0.00E+00
198	WELD 2-EM-05-S007-C	5.190	122.619	177.381	0.00E+00
199	WELD 2-EM-05-W566538-F006	5.190	122.765	177.235	0.00E+00
200	WELD 2-BB-01-S102-6	2.120	98.145	201.855	0.00E+00
201	WELD 2-BB-14-F006	2.630	97.771	202.229	0.00E+00
202	WELD 2-BB-14-F001	2.630	101.155	198.845	0.00E+00
203	WELD 2-BB-01-S305-5	2.630	102.739	197.261	0.00E+00
204	WELD 2-BB-01-S305-6	2.630	104.019	195.981	0.00E+00
205	WELD EBB01C-RSG-OUTLET-SC010	31.000	1043.018	-743.018	1.16E-08
206	WELD 2-BB-01-3065C-WDC-002-FW2	31.000	1040.097	-740.097	1.20E-08
207	WELD 2-BB-01-F306	31.000	1024.979	-724.979	1.36E-08
208	WELD 2-BB-01-S304-3	31.000	1020.473	-720.473	1.26E-08
209	WELD 2-BB-01-F308	31.000	936.096	-636.096	1.28E-08
210	WELD 2-BB-01-S305-4	31.000	902.157	-602.157	1.46E-08
211	WELD 2-BB-01-F307	31.000	832.546	-532.546	1.30E-08
212	WELD 2-EP-02-F019	8.750	234.075	65.925	0.00E+00
213	WELD 2-EP-02-S009-E	8.750	227.107	72.893	0.00E+00
214	WELD 2-EP-02-S009-D	8.750	214.368	85.632	0.00E+00
215	WELD 2-EP-02-S009-C	8.750	206.341	93.659	0.00E+00
216	WELD 2-EP-02-F018	8.750	210.260	89.740	0.00E+00
217	WELD 2-BG-22-F001	2.630	101.259	198.741	0.00E+00
218	WELD 2-BG-22-S001-A	2.630	97.304	202.696	0.00E+00
219	WELD 2-BG-22-S001-B	2.630	84.554	215.446	0.00E+00
220	WELD 2-BG-22-S001-C	2.630	84.865	215.135	0.00E+00
221	WELD 2-BG-22-S001-D	2.630	85.603	214.397	0.00E+00
222	WELD 2-BG-22-S001-G	2.630	85.073	214.927	0.00E+00
223	WELD 2-BG-22-F002	2.630	85.005	214.995	0.00E+00
224	WELD 2-EM-03-F016	5.190	132.674	167.326	0.00E+00
225	WELD 2-EM-03-S015-C	5.190	117.352	182.648	0.00E+00
226	WELD 2-EM-03-S015-B	5.190	112.044	187.956	0.00E+00
227	WELD 2-EM-03-F015	5.190	113.846	186.154	0.00E+00
228	WELD 2-HB-24-FW051	1.690	82.181	217.819	0.00E+00
229	WELD 2-HB-24-FW052	1.690	83.224	216.776	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
230	WELD 2-BG-22-S001-F	1.690	83.080	216.920	0.00E+00
231	WELD 2-BB-01-S301-6	8.750	243.323	56.677	0.00E+00
232	WELD 2-BB-01-S301-3	1.690	89.223	210.777	0.00E+00
233	WELD 2-BB-01-S301-4	2.120	97.544	202.456	0.00E+00
234	WELD 2-RV-302-121-C	27.500	197.365	102.635	0.00E+00
235	WELD 2-BB-01-F302	27.500	200.530	99.470	0.00E+00
236	WELD 2-BB-01-S301-2	27.500	212.821	87.179	0.00E+00
237	WELD 2-BB-01-F301	27.500	802.507	-502.507	1.02E-08
238	WELD 2-BB-01-S302-3	5.190	134.620	165.380	0.00E+00
239	WELD 2-RV-301-121-C	29.000	290.914	9.086	0.00E+00
240	WELD 2-BB-01-F303	29.000	204.365	95.635	0.00E+00
241	WELD 2-BB-01-S302-2	29.000	1062.241	-762.241	4.30E-09
242	WELD 2-BB-01-3065C-WDC-001-FW1	29.000	1075.066	-775.066	5.58E-09
243	WELD EBB01C-RSG-INLET-SC010	29.000	1074.732	-774.732	5.51E-09
244	WELD 2-BB-09-FW152	1.690	79.879	220.121	0.00E+00
245	WELD 2-BB-09-FW151	1.690	79.281	220.719	0.00E+00
246	WELD 2-BB-09-FW148	1.690	78.817	221.183	0.00E+00
247	WELD 2-BB-09-FW147	1.690	78.800	221.200	0.00E+00
248	WELD 2-BB-09-FW142	1.690	79.117	220.883	0.00E+00
249	WELD 2-BB-09-FW141	1.690	80.391	219.609	0.00E+00
250	WELD 2-BB-09-V181-2	1.690	80.376	219.624	0.00E+00
251	WELD 2-BB-09-FW153-A	1.340	79.418	220.582	0.00E+00
252	WELD 2-BB-09-FW154-A	1.340	79.875	220.125	0.00E+00
253	WELD 2-BB-04-S002-L	1.690	86.133	213.867	0.00E+00
254	WELD 2-BG-24-FW068	1.690	85.710	214.290	0.00E+00
255	WELD 2-BG-24-FW067	1.690	81.623	218.377	0.00E+00
256	WELD 2-BG-24-BB-V084-2	1.690	81.555	218.445	0.00E+00
257	WELD 2-BG-24-FW062	1.690	81.555	218.445	0.00E+00
258	WELD 2-BB-02-F006	5.190	181.246	118.754	0.00E+00
259	WELD 2-TBB03-3-C-W	5.190	181.246	118.754	0.00E+00
260	WELD 2-BB-02-S007-B	5.190	173.744	126.256	0.00E+00
261	WELD 2-BB-02-S007-D	5.190	161.387	138.613	0.00E+00
262	WELD 2-BB-02-S007-E	5.190	151.677	148.323	0.00E+00
263	WELD 2-BB-02-S007-F	5.190	151.603	148.397	0.00E+00
264	WELD 2-BB-02-S007-G	5.190	161.811	138.189	0.00E+00
265	WELD 2-BB-02-S007-J	5.190	142.705	157.295	0.00E+00
266	WELD 2-BB-02-S001-J	5.190	138.966	161.034	0.00E+00
267	WELD 2-BB-02-S001-G	5.190	154.270	145.730	0.00E+00
268	WELD 2-BB-02-S001-F	5.190	143.175	156.825	0.00E+00
269	WELD 2-BB-02-S001-E	5.190	142.130	157.870	0.00E+00
270	WELD 2-BB-02-S001-D	5.190	148.966	151.034	0.00E+00
271	WELD 2-BB-02-S001-B	5.190	162.660	137.340	0.00E+00
272	WELD 2-TBB03-3-A-W	5.190	171.634	128.366	0.00E+00
273	WELD 2-BB-02-F001	5.190	171.634	128.366	0.00E+00
274	WELD 2-TBB03-3-B-W	5.190	176.739	123.261	0.00E+00
275	WELD 2-BB-02-F005	5.190	176.739	123.261	0.00E+00
276	WELD 2-BB-02-S006-B	5.190	167.402	132.598	0.00E+00
277	WELD 2-BB-02-S006-D	5.190	153.813	146.187	0.00E+00
278	WELD 2-BB-02-S006-E	5.190	148.017	151.983	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
279	WELD 2-BB-02-S006-F	5.190	149.480	150.520	0.00E+00
280	WELD 2-BB-02-S006-G	5.190	160.374	139.626	0.00E+00
281	WELD 2-BB-02-S006-J	5.190	146.561	153.439	0.00E+00
282	WELD 2-BB-04-F001	3.440	123.330	176.670	0.00E+00
283	WELD 2-TBB03-2-W	3.440	123.330	176.670	0.00E+00
284	WELD 2-BB-04-S001-D	3.440	104.391	195.609	0.00E+00
285	WELD 2-BB-04-S001-C	3.440	99.680	200.320	0.00E+00
286	WELD 2-BB-04-F023	3.440	98.698	201.302	0.00E+00
287	WELD 2-BB-04-F002	3.440	85.411	214.589	0.00E+00
288	WELD 2-BB-04-S002-R	3.440	85.630	214.370	0.00E+00
289	WELD 2-BB-04-S002-N	3.440	86.503	213.497	0.00E+00
290	WELD 2-BB-02-F008	5.190	179.281	120.719	0.00E+00
291	WELD 2-TBB03-4-W	5.190	179.281	120.719	0.00E+00
292	WELD 2-BB-02-S009-B	5.190	163.164	136.836	0.00E+00
293	WELD 2-BB-02-S009-C	5.190	154.260	145.740	0.00E+00
294	WELD 2-BB-02-FW1	5.190	139.009	160.991	0.00E+00
295	WELD 2-BB-02-S009-E	5.190	125.146	174.854	0.00E+00
296	WELD 2-BB-02-F009	5.190	79.140	220.860	0.00E+00
297	WELD 2-BB-02-S010-B	5.190	78.970	221.030	0.00E+00
298	WELD 2-BB-02-FW2	5.190	78.970	221.030	0.00E+00
299	WELD 2-BB-02-F016	2.630	78.800	221.200	0.00E+00
300	WELD 2-BB-02-S014-B	2.630	78.800	221.200	0.00E+00
301	WELD 2-BB-02-S014-C	2.630	78.800	221.200	0.00E+00
302	WELD 2-BB-02-F017-A	2.630	78.800	221.200	0.00E+00
303	WELD 2-BB-02-F010	2.630	78.800	221.200	0.00E+00
304	WELD 2-BB-02-S010-H	2.630	78.800	221.200	0.00E+00
305	WELD 2-BB-02-S010-G	2.630	78.800	221.200	0.00E+00
306	WELD 2-BB-02-S010-F	2.630	78.800	221.200	0.00E+00
307	WELD 2-BB-02-FW25	2.630	78.800	221.200	0.00E+00
308	WELD 2-BB-02-FW3	2.630	78.800	221.200	0.00E+00
309	WELD 2-BB-04-S002-D	3.440	93.725	206.275	0.00E+00
310	WELD 2-BB-04-FW6	3.440	92.460	207.540	0.00E+00
311	WELD 2-BB-04-S002-B	3.440	92.209	207.791	0.00E+00
312	WELD 2-BB-04-F004	3.440	92.703	207.297	0.00E+00
313	WELD 2-BB-04-S002-M	5.190	94.770	205.230	0.00E+00
314	WELD 2-BB-04-S002-K	5.190	110.293	189.707	0.00E+00
315	WELD 2-BB-04-S002-J	5.190	112.027	187.973	0.00E+00
316	WELD 2-BB-04-S002-E	5.190	112.160	187.840	0.00E+00
317	WELD 2-BB-04-F003	5.190	110.940	189.060	0.00E+00
318	WELD 2-BB-04-S011-M	5.190	110.578	189.422	0.00E+00
319	WELD 2-BB-04-S011-L	5.190	111.426	188.574	0.00E+00
320	WELD 2-BB-04-S011-J	5.190	105.472	194.528	0.00E+00
321	WELD 2-BB-04-S011-H	5.190	103.817	196.183	0.00E+00
322	WELD 2-BB-04-S011-D	5.190	104.493	195.507	0.00E+00
323	WELD 2-BB-04-S011-C	3.440	90.645	209.355	0.00E+00
324	WELD 2-BB-04-FW5	3.440	89.889	210.111	0.00E+00
325	WELD 2-BB-04-S011-A	3.440	89.855	210.145	0.00E+00
326	WELD 2-BB-04-F014	3.440	90.599	209.401	0.00E+00
327	WELD 2-BB-01-S402-4	10.500	276.991	23.009	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
328	WELD 2-BB-01-S402-3	11.190	285.284	14.716	0.00E+00
329	WELD 2-RV-301-121-D	29.000	282.663	17.337	0.00E+00
330	WELD 2-BB-01-F403	29.000	198.138	101.862	0.00E+00
331	WELD 2-BB-01-S402-2	29.000	1154.102	-854.102	7.48E-09
332	WELD 2-BB-01-3065D-WDC-001-FW1	29.000	1157.052	-857.052	9.23E-09
333	WELD EBB01D-RSG-INLET-SC010	29.000	1156.179	-856.179	9.08E-09
334	WELD 2-BB-01-S401-7	8.750	249.179	50.821	0.00E+00
335	WELD 2-BB-01-S401-3	1.690	89.216	210.784	0.00E+00
336	WELD 2-BB-01-S401-4	2.120	96.343	203.657	0.00E+00
337	WELD 2-RV-302-121-D	27.500	167.819	132.181	0.00E+00
338	WELD 2-BB-01-F402	27.500	171.782	128.218	0.00E+00
339	WELD 2-BB-01-S401-2	27.500	199.030	100.970	0.00E+00
340	WELD 2-BB-01-F401	27.500	931.142	-631.142	1.41E-08
341	WELD 2-BB-15-F006	2.630	108.796	191.204	0.00E+00
342	WELD 2-BB-15-F001	2.630	110.866	189.134	0.00E+00
343	WELD 2-BB-01-S405-5	2.630	111.426	188.574	0.00E+00
344	WELD 2-BB-01-S405-6	1.690	88.263	211.737	0.00E+00
345	WELD EBB01D-RSG-OUTLET-SC010	31.000	1139.034	-839.034	1.42E-08
346	WELD 2-BB-01-3065D-WDC-002-FW2	31.000	1137.556	-837.556	1.45E-08
347	WELD 2-BB-01-F406	31.000	1127.905	-827.905	1.63E-08
348	WELD 2-BB-01-S404-3	31.000	1127.648	-827.648	1.66E-08
349	WELD 2-BB-01-F408	31.000	1077.615	-777.615	1.68E-08
350	WELD 2-BB-01-S405-4	31.000	1049.937	-749.937	1.77E-08
351	WELD 2-BB-01-F407	31.000	997.012	-697.012	1.68E-08
352	WELD 2-EP-01-F019	8.750	200.131	99.869	0.00E+00
353	WELD 2-EP-01-S010-C	8.750	202.719	97.281	0.00E+00
354	WELD 2-EP-01-S010-D	8.750	220.370	79.630	0.00E+00
355	WELD 2-EP-01-S010-E	8.750	237.692	62.308	0.00E+00
356	WELD 2-EP-01-F020	8.750	245.191	54.809	0.00E+00
357	WELD 2-EJ-04-S016-F	5.190	133.818	166.182	0.00E+00
358	WELD 2-EJ-04-F029	5.190	138.986	161.014	0.00E+00
359	WELD 2-EM-05-S005-C	5.190	148.192	151.808	0.00E+00
360	WELD 2-EM-05-S005-B	5.190	149.483	150.517	0.00E+00
361	WELD 2-EM-05-F004	5.190	149.126	150.874	0.00E+00
362	WELD 2-EJ-04-F026	10.500	298.411	1.589	0.00E+00
363	WELD 2-EJ-04-S016-B	10.500	310.438	-10.438	0.00E+00
364	WELD 2-EJ-04-S016-C	10.500	318.508	-18.508	0.00E+00
365	WELD 2-EJ-04-S016-D	10.500	316.902	-16.902	0.00E+00
366	WELD 2-EJ-04-S016-E	10.500	340.531	-40.531	3.78E-10
367	WELD 2-EJ-04-S016-G	10.500	380.306	-80.306	2.26E-09
368	WELD 2-EJ-04-S016-H	10.500	403.032	-103.032	0.00E+00
369	WELD 2-EJ-04-F025	10.500	431.900	-131.900	7.67E-10
370	WELD 2-BB-07-FW004	1.340	79.316	220.684	0.00E+00
371	WELD 2-BB-07-FW003	1.340	79.501	220.499	0.00E+00
372	WELD 2-BB-07-FW002	1.340	79.602	220.398	0.00E+00
373	WELD 2-BB-07-FW001	1.340	80.046	219.954	0.00E+00
374	WELD 2-BB-07-FW005	1.690	80.000	220.000	0.00E+00
375	WELD 2-BB-07-FW006	1.690	79.683	220.317	0.00E+00
376	WELD 2-BB-07-FW007	1.690	79.252	220.748	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
377	WELD 2-BB-07-FW008	1.690	78.800	221.200	0.00E+00
378	WELD 2-BB-07-FW011	1.690	78.800	221.200	0.00E+00
379	WELD 2-BB-07-FW012	1.690	78.800	221.200	0.00E+00
380	WELD 2-BB-07-FW013	1.690	78.800	221.200	0.00E+00
381	WELD 2-BB-07-FW014	1.690	78.800	221.200	0.00E+00
382	WELD 2-BB-07-FW019	1.690	78.800	221.200	0.00E+00
383	WELD 2-BB-07-FW020	1.690	78.800	221.200	0.00E+00
384	WELD 2-BB-07-FW021	1.690	78.800	221.200	0.00E+00
385	WELD 2-BB-07-FW022	1.690	78.844	221.156	0.00E+00
386	WELD 2-BB-07-FW023	1.690	78.800	221.200	0.00E+00
387	WELD 2-BB-07-FW024	1.690	78.800	221.200	0.00E+00
388	WELD 2-BB-07-FW029	1.690	78.800	221.200	0.00E+00
389	WELD 2-BB-07-V211-2	1.690	78.800	221.200	0.00E+00
390	WELD 2-BG-21-F026	2.630	101.482	198.518	0.00E+00
391	WELD 2-BG-21-F027	2.630	105.771	194.229	0.00E+00
392	WELD 2-BB-01-S401-5	2.630	108.802	191.198	0.00E+00
393	WELD 2-BG-23-FW144	1.690	82.410	217.590	0.00E+00
394	WELD 2-BG-23-FW-3	1.690	82.535	217.465	0.00E+00
395	WELD 2-BG-23-FW-4	1.690	82.823	217.177	0.00E+00
396	WELD 2-BG-23-FW-5	1.690	82.754	217.246	0.00E+00
397	WELD 2-BG-23-FW145	1.690	81.805	218.195	0.00E+00
398	WELD 2-BG-23-FW149	1.690	82.831	217.169	0.00E+00
399	WELD 2-BG-23-FW148	1.690	82.583	217.417	0.00E+00
400	WELD 2-BG-23-FW143	1.690	82.114	217.886	0.00E+00
401	WELD 2-BG-23-A175752A-FW02	1.690	83.055	216.945	0.00E+00
402	WELD 2-BG-23-A175752A-FW01	1.690	83.653	216.347	0.00E+00
403	WELD 2-BG-23-FW138	1.690	87.995	212.005	0.00E+00
404	WELD 2-BG-22-F025	2.630	83.841	216.159	0.00E+00
405	WELD 2-BG-22-S020-A	2.630	82.407	217.593	0.00E+00
406	WELD 2-BG-22-S020-B	2.630	82.480	217.520	0.00E+00
407	WELD 2-BG-22-F026	2.630	82.558	217.442	0.00E+00
408	WELD 2-BG-23-FW150	1.690	82.563	217.437	0.00E+00
409	WELD 2-BG-23-FW151	1.690	81.904	218.096	0.00E+00
410	WELD 2-BG-23-FW152	1.690	81.580	218.420	0.00E+00
411	WELD 2-BG-23-FW153	1.690	81.534	218.466	0.00E+00
					5.37E-07

10.2 **Full Weld List for Valve Insulation Sensitivity Scenario**

This section contains a full weld list for the valve insulation sensitivity scenario. Table 10-2 lists the weld location name, the corresponding pipe diameter (DEGB size), the amount of fiber transported by a DEGB, the fiber margin (the difference between the RoverD failure threshold and the amount of fiber transported), and the contribution of each weld to the geometric mean ∆CDF based on 25-year NUREG-1829 frequencies at the smallest critical break size. Welds that do not exceed the RoverD limit for a DEGB are deemed non-critical welds. Non-critical welds have a positive fiber margin and do not contribute to ΔCDF. Note that per weld contributions to ΔCDF in the last column sum to the mean ΔCDF reported for the baseline scenario reported in Table 9-2.

Table 10-2: Full weld list for valve insulation sensitivity scenario

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ΔCDF
1	WELD 2-BB-04-F005	3.440	96.193	203.807	0.00E+00
2	WELD 2-BB-04-S003-D	3.440	97.643	202.357	0.00E+00
3	WELD 2-BB-04-S003-C	3.440	98.621	201.379	0.00E+00
4	WELD 2-BB-04-F006	3.440	103.704	196.296	0.00E+00
5	WELD 2-BB-04-S004-C	3.440	107.348	192.652	0.00E+00
6	WELD 2-BB-04-F007	3.440	105.538	194.462	0.00E+00
7	WELD 2-BB-04-S005-D	3.440	107.144	192.856	0.00E+00
8	WELD 2-BB-04-S005-C	3.440	105.531	194.469	0.00E+00
9	WELD 2-BB-04-S005-B	3.440	98.012	201.988	0.00E+00
10	WELD 2-BB-04-F008	3.440	98.011	201.989	0.00E+00
11	WELD 2-BB-04-S006-C	3.440	93.206	206.794	0.00E+00
12	WELD 2-BB-04-S006-B	3.440	91.505	208.495	0.00E+00
13	WELD 2-BB-04-F009	3.440	87.065	212.935	0.00E+00
14	WELD 2-BB-04-S007-F	3.440	87.235	212.765	0.00E+00
15	WELD 2-BB-04-S007-E	3.440	88.794	211.206	0.00E+00
16	WELD 2-BB-04-S007-D	3.440	88.661	211.339	0.00E+00
17	WELD 2-BB-04-S007-B	3.440	88.421	211.579	0.00E+00
18	WELD 2-BB-04-F010	3.440	88.433	211.567	0.00E+00
19	WELD 2-BB-04-S008-D	3.440	88.422	211.578	0.00E+00
20	WELD 2-BB-04-S008-C	3.440	88.403	211.597	0.00E+00
21	WELD 2-BB-04-S008-B	3.440	88.671	211.329	0.00E+00
22	WELD 2-BB-04-F011	3.440	88.159	211.841	0.00E+00
23	WELD 2-BB-04-S009-D	3.440	106.447	193.553	0.00E+00
24	WELD 2-BB-04-S009-C	3.440	108.635	191.365	0.00E+00
25	WELD 2-BB-04-S009-B	3.440	116.486	183.514	0.00E+00
26	WELD 2-BB-04-F012	3.440	119.125	180.875	0.00E+00
27	WELD 2-BB-01-S101-5	3.440	123.402	176.598	0.00E+00
28	WELD 2-BB-04-F015	3.440	92.392	207.608	0.00E+00
29	WELD 2-BB-04-S012-F	3.440	91.321	208.679	0.00E+00
30	WELD 2-BB-04-S012-E	3.440	91.777	208.223	0.00E+00
31	WELD 2-BB-04-S012-D	3.440	94.777	205.223	0.00E+00
32	WELD 2-BB-04-S012-C	3.440	94.006	205.994	0.00E+00
33	WELD 2-BB-04-F016	3.440	96.859	203.141	0.00E+00
34	WELD 2-BB-04-S013-F	3.440	99.468	200.532	0.00E+00
35	WELD 2-BB-04-S013-H	3.440	98.851	201.149	0.00E+00
36	WELD 2-BB-04-S013-D	3.440	101.795	198.205	0.00E+00
37	WELD 2-BB-04-S013-C	3.440	102.798	197.202	0.00E+00
38	WELD 2-BB-04-S013-B	3.440	102.469	197.531	0.00E+00
39	WELD 2-BB-04-F017	3.440	102.978	197.022	0.00E+00
40	WELD 2-BB-04-S014-E	3.440	89.674	210.326	0.00E+00
41	WELD 2-BB-04-S014-D	3.440	88.802	211.198	0.00E+00
42	WELD 2-BB-04-S014-C	3.440	88.277	211.723	0.00E+00
43	WELD 2-BB-04-S014-B	3.440	88.390	211.610	0.00E+00
44	WELD 2-BB-04-F018	3.440	91.391	208.609	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
45	WELD 2-BB-04-S015-F	3.440	91.404	208.596	0.00E+00
46	WELD 2-BB-04-S015-E	3.440	88.741	211.259	0.00E+00
47	WELD 2-BB-04-S015-D	3.440	88.717	211.283	0.00E+00
48	WELD 2-BB-04-S015-B	3.440	88.429	211.571	0.00E+00
49	WELD 2-BB-04-F019	3.440	88.425	211.575	0.00E+00
50	WELD 2-BB-04-FW2	3.440	88.383	211.617	0.00E+00
51	WELD 2-BB-04-S016-C	3.440	88.354	211.646	0.00E+00
52	WELD 2-BB-04-S016-B	3.440	84.471	215.529	0.00E+00
53	WELD 2-BB-04-F020	3.440	84.712	215.288	0.00E+00
54	WELD 2-BB-04-S017-B	3.440	85.368	214.632	0.00E+00
55	WELD 2-BB-04-F021	3.440	85.865	214.135	0.00E+00
56	WELD 2-BB-04-S018-D	3.440	114.235	185.765	0.00E+00
57	WELD 2-BB-04-S018-C	3.440	114.904	185.096	0.00E+00
58	WELD 2-BB-04-S018-B	3.440	117.401	182.599	0.00E+00
59	WELD 2-BB-04-F022	3.440	120.151	179.849	0.00E+00
60	WELD 2-EM-03-BBV059-2	1.340	81.266	218.734	0.00E+00
61	WELD 2-EM-03-FW225	1.340	81.174	218.826	0.00E+00
62	WELD 2-EM-03-FW226	1.340	80.281	219.719	0.00E+00
63	WELD 2-EM-03-FW227	1.340	83.183	216.817	0.00E+00
64	WELD 2-BB-01-S401-6	2.630	108.123	191.877	0.00E+00
65	WELD 2-BB-01-S401-10	2.630	107.102	192.898	0.00E+00
66	WELD 2-EM-03-FW259	1.340	83.669	216.331	0.00E+00
67	WELD 2-EM-03-FW258	1.340	80.368	219.632	0.00E+00
68	WELD 2-EM-03-BBV040-2	1.340	80.366	219.634	0.00E+00
69	WELD 2-BB-01-S301-5	2.630	112.256	187.744	0.00E+00
70	WELD 2-BB-01-S301-9	2.630	110.184	189.816	0.00E+00
71	WELD 2-HB-24-FW67	1.690	87.849	212.151	0.00E+00
72	WELD 2-HB-24-FW66	1.690	86.476	213.524	0.00E+00
73	WELD 2-HB-24-FW065	1.690	85.407	214.593	0.00E+00
74	WELD 2-HB-24-FW064	1.690	82.426	217.574	0.00E+00
75	WELD 2-BB-01-F004	11.190	173.660	126.340	0.00E+00
76	WELD 2-TBB03-1-W	11.190	173.660	126.340	0.00E+00
77	WELD 2-BB-01-S003-3	11.190	181.889	118.111	0.00E+00
78	WELD 2-BB-01-S003-2	11.190	201.121	98.879	0.00E+00
79	WELD 2-BB-01-S003-8	11.190	245.809	54.191	0.00E+00
80	WELD 2-BB-01-F003	11.190	187.369	112.631	0.00E+00
81	WELD 2-BB-01-F002	11.190	206.374	93.626	0.00E+00
82	WELD 2-BB-01-S001-6	11.190	191.730	108.270	0.00E+00
83	WELD 2-BB-01-F001	11.190	283.721	16.279	0.00E+00
84	WELD 2-BB-01-S101-8	2.630	109.163	190.837	0.00E+00
85	WELD 2-BG-21-F014	2.630	106.172	193.828	0.00E+00
86	WELD 2-BG-21-FW-1	2.630	94.047	205.953	0.00E+00
87	WELD 2-BG-21-S010-D	2.630	87.327	212.673	0.00E+00
88	WELD 2-BG-21-S010-C	2.630	85.603	214.397	0.00E+00
89	WELD 2-BG-21-S010-B	2.630	86.262	213.738	0.00E+00
90	WELD 2-BG-21-S010-A	2.630	86.093	213.907	0.00E+00
91	WELD 2-BG-21-F013	2.630	84.796	215.204	0.00E+00
92	WELD 2-EP-02-F008	8.750	262.342	37.658	0.00E+00
93	WELD 2-EP-02-S004-E	8.750	259.279	40.721	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
94	WELD 2-EP-02-FW2	8.750	249.854	50.146	0.00E+00
95	WELD 2-EP-02-S004-C	8.750	232.209	67.791	0.00E+00
96	WELD 2-EP-02-F007	8.750	230.921	69.079	0.00E+00
97	WELD 2-EM-03-F012	5.190	128.111	171.889	0.00E+00
98	WELD 2-EM-03-S012-D	5.190	126.707	173.293	0.00E+00
99	WELD 2-EM-03-S012-B	5.190	123.221	176.779	0.00E+00
100	WELD 2-EM-03-W237498-FW03	5.190	122.294	177.706	0.00E+00
101	WELD 2-BB-11-C600739-FW01	1.340	79.817	220.183	0.00E+00
102	WELD 2-BB-11-A600739B-FW01	1.340	79.429	220.571	0.00E+00
103	WELD 2-BB-11-FW008	1.690	78.800	221.200	0.00E+00
104	WELD 2-BB-11-FW011	1.690	78.800	221.200	0.00E+00
105	WELD 2-BB-11-FW012	1.690	78.800	221.200	0.00E+00
106	WELD 2-BB-11-FW013	1.690	78.800	221.200	0.00E+00
107	WELD 2-BB-11-FW014	1.690	80.321	219.679	0.00E+00
108	WELD 2-BB-11-FW015	1.690	80.019	219.981	0.00E+00
109	WELD 2-BB-11-FW016	1.690	79.903	220.097	0.00E+00
110	WELD 2-BB-11-V151-2	1.690	79.801	220.199	0.00E+00
111	WELD 2-EM-03-FW269	1.340	83.233	216.767	0.00E+00
112	WELD 2-EM-03-FW268	1.340	81.483	218.517	0.00E+00
113	WELD 2-EM-03-BBV022-2	1.340	81.313	218.687	0.00E+00
114	WELD 2-BB-01-S201-8	2.630	99.038	200.962	0.00E+00
115	WELD 2-BB-01-S201-15	2.630	98.619	201.381	0.00E+00
116	WELD 2-BB-06-F006	2.630	98.006	201.994	0.00E+00
117	WELD 2-BB-06-F001	2.630	101.122	198.878	0.00E+00
118	WELD 2-BB-01-S205-5	2.630	102.665	197.335	0.00E+00
119	WELD 2-BB-01-S205-6	1.690	88.213	211.787	0.00E+00
120	WELD EBB01B-RSG-OUTLET-SC010	31.000	1111.688	-811.688	1.09E-08
121	WELD 2-BB-01-3065B-WDC-002-FW2	31.000	1108.769	-808.769	1.11E-08
122	WELD 2-BB-01-F206	31.000	1094.319	-794.319	1.20E-08
123	WELD 2-BB-01-S204-3	31.000	1076.967	-776.967	1.08E-08
124	WELD 2-BB-01-F208	31.000	992.323	-692.323	1.19E-08
125	WELD 2-BB-01-S205-4	31.000	991.007	-691.007	1.36E-08
126	WELD 2-BB-01-F207	31.000	996.062	-696.062	1.19E-08
127	WELD 2-BB-01-S201-7	8.750	266.859	33.141	0.00E+00
128	WELD 2-BB-01-S201-3	1.690	89.972	210.028	0.00E+00
129	WELD 2-BB-01-S201-4	2.120	97.072	202.928	0.00E+00
130	WELD 2-BB-01-S201-5	3.440	124.006	175.994	0.00E+00
131	WELD 2-RV-302-121-B	27.500	287.117	12.883	0.00E+00
132	WELD 2-BB-01-F202	27.500	290.094	9.906	0.00E+00
133	WELD 2-BB-01-S201-2	27.500	317.064	-17.064	0.00E+00
134	WELD 2-BB-01-F201	27.500	939.781	-639.781	1.20E-08
135	WELD 2-BB-01-S202-3	5.190	130.149	169.851	0.00E+00
136	WELD 2-RV-301-121-B	29.000	272.120	27.880	0.00E+00
137	WELD 2-BB-01-F203	29.000	197.316	102.684	0.00E+00
138	WELD 2-BB-01-S202-2	29.000	1115.525	-815.525	4.70E-09
139	WELD 2-BB-01-3065B-WDC-001-FW1	29.000	1124.796	-824.796	4.86E-09
140	WELD EBB01B-RSG-INLET-SC010	29.000	1122.633	-822.633	4.76E-09
141	WELD 2-EM-03-FW235	1.340	83.374	216.626	0.00E+00
142	WELD 2-EM-03-FW234	1.340	81.061	218.939	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
143	WELD 2-EM-03-BBV001-2	1.340	81.005	218.995	0.00E+00
144	WELD 2-BB-01-S101-9	2.630	100.782	199.218	0.00E+00
145	WELD 2-BB-01-S101-13	2.630	99.992	200.008	0.00E+00
146	WELD 2-EJ-04-F030	10.500	298.232	1.768	0.00E+00
147	WELD 2-EJ-04-FW9	10.500	328.112	-28.112	0.00E+00
148	WELD 2-EJ-04-S018-C	10.500	329.742	-29.742	0.00E+00
149	WELD 2-EJ-04-FW8	10.500	327.464	-27.464	0.00E+00
150	WELD 2-EJ-04-S018-E	10.500	351.483	-51.483	0.00E+00
151	WELD 2-EJ-04-F031	10.500	408.111	-108.111	1.17E-09
152	WELD 2-BB-08-FW041-A-R-1	1.690	79.052	220.948	0.00E+00
153	WELD 2-BB-08-FW099	1.690	79.021	220.979	0.00E+00
154	WELD 2-BB-08-FW044	1.690	78.910	221.090	0.00E+00
155	WELD 2-BB-08-FW045	1.690	78.800	221.200	0.00E+00
156	WELD 2-BB-08-FW046-A	1.690	78.800	221.200	0.00E+00
157	WELD 2-BB-08-FW047	1.690	78.800	221.200	0.00E+00
158	WELD 2-BB-08-FW052-B	1.690	78.800	221.200	0.00E+00
159	WELD 2-BB-08-FW053	1.690	78.800	221.200	0.00E+00
160	WELD 2-BB-08-V121-2	1.690	78.800	221.200	0.00E+00
161	WELD 2-BB-08-FW039	1.340	79.883	220.117	0.00E+00
162	WELD 2-BB-08-FW040	1.340	78.800	221.200	0.00E+00
163	WELD 2-BB-05-F006	2.630	110.123	189.877	0.00E+00
164	WELD 2-BB-05-F001	2.630	111.485	188.515	0.00E+00
165	WELD 2-BB-01-S105-5	2.630	111.691	188.309	0.00E+00
166	WELD 2-BB-01-S105-6	1.690	88.356	211.644	0.00E+00
167	WELD EBB01A-RSG-OUTLET-SC010	31.000	1131.242	-831.242	1.37E-08
168	WELD 2-BB-01-3065A-WDC-002-FW2	31.000	1129.313	-829.313	1.40E-08
169	WELD 2-BB-01-F106	31.000	1113.144	-813.144	1.60E-08
170	WELD 2-BB-01-S104-3	31.000	1096.598	-796.598	1.61E-08
171	WELD 2-BB-01-F108	31.000	1032.886	-732.886	1.61E-08
172	WELD 2-BB-01-S105-4	31.000	1039.665	-739.665	1.79E-08
173	WELD 2-BB-01-F107	31.000	1034.681	-734.681	1.68E-08
174	WELD 2-BB-01-S102-3	10.500	285.421	14.579	0.00E+00
175	WELD 2-RV-301-121-A	29.000	292.660	7.340	0.00E+00
176	WELD 2-BB-01-F103	29.000	201.121	98.879	0.00E+00
177	WELD 2-BB-01-S102-2	29.000	1147.549	-847.549	9.45E-09
178	WELD 2-BB-01-3065A-WDC-001-FW1	29.000	1149.820	-849.820	1.02E-08
179	WELD EBB01A-RSG-INLET-SC010	29.000	1147.387	-847.387	1.00E-08
180	WELD 2-BB-01-S101-7	8.750	298.102	1.898	0.00E+00
181	WELD 2-BB-01-S101-3	1.690	89.457	210.543	0.00E+00
182	WELD 2-RV-302-121-A	27.500	305.896	-5.896	8.41E-11
183	WELD 2-BB-01-F102	27.500	309.510	-9.510	1.36E-10
184	WELD 2-BB-01-S101-2	27.500	348.521	-48.521	0.00E+00
185	WELD 2-BB-01-F101	27.500	990.611	-690.611	1.51E-08
186	WELD 2-HB-24-FW001	1.690	88.017	211.983	0.00E+00
187	WELD 2-HB-24-FW002	1.690	86.761	213.239	0.00E+00
188	WELD 2-HB-24-FW078	1.690	85.640	214.360	0.00E+00
189	WELD 2-HB-24-FW079-A	1.690	80.963	219.037	0.00E+00
190	WELD 2-EP-01-F008	8.750	273.860	26.140	0.00E+00
191	WELD 2-EP-01-S004-E	8.750	268.120	31.880	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
192	WELD 2-EP-01-S004-D	8.750	254.212	45.788	0.00E+00
193	WELD 2-EP-01-S004-C	8.750	235.325	64.675	0.00E+00
194	WELD 2-EP-01-F007	8.750	233.631	66.369	0.00E+00
195	WELD 2-EJ-04-S018-F	5.190	125.978	174.022	0.00E+00
196	WELD 2-EM-05-F007	5.190	123.837	176.163	0.00E+00
197	WELD 2-EM-05-S007-D	5.190	123.095	176.905	0.00E+00
198	WELD 2-EM-05-S007-C	5.190	122.619	177.381	0.00E+00
199	WELD 2-EM-05-W566538-F006	5.190	122.765	177.235	0.00E+00
200	WELD 2-BB-01-S102-6	2.120	98.145	201.855	0.00E+00
201	WELD 2-BB-14-F006	2.630	97.771	202.229	0.00E+00
202	WELD 2-BB-14-F001	2.630	101.155	198.845	0.00E+00
203	WELD 2-BB-01-S305-5	2.630	102.739	197.261	0.00E+00
204	WELD 2-BB-01-S305-6	2.630	104.019	195.981	0.00E+00
205	WELD EBB01C-RSG-OUTLET-SC010	31.000	1058.000	-758.000	1.18E-08
206	WELD 2-BB-01-3065C-WDC-002-FW2	31.000	1055.079	-755.079	1.21E-08
207	WELD 2-BB-01-F306	31.000	1040.015	-740.015	1.37E-08
208	WELD 2-BB-01-S304-3	31.000	1035.374	-735.374	1.27E-08
209	WELD 2-BB-01-F308	31.000	951.012	-651.012	1.30E-08
210	WELD 2-BB-01-S305-4	31.000	917.044	-617.044	1.49E-08
211	WELD 2-BB-01-F307	31.000	847.433	-547.433	1.32E-08
212	WELD 2-EP-02-F019	8.750	234.525	65.475	0.00E+00
213	WELD 2-EP-02-S009-E	8.750	227.545	72.455	0.00E+00
214	WELD 2-EP-02-S009-D	8.750	214.805	85.195	0.00E+00
215	WELD 2-EP-02-S009-C	8.750	206.778	93.222	0.00E+00
216	WELD 2-EP-02-F018	8.750	211.648	88.352	0.00E+00
217	WELD 2-BG-22-F001	2.630	101.259	198.741	0.00E+00
218	WELD 2-BG-22-S001-A	2.630	97.304	202.696	0.00E+00
219	WELD 2-BG-22-S001-B	2.630	84.958	215.042	0.00E+00
220	WELD 2-BG-22-S001-C	2.630	85.595	214.405	0.00E+00
221	WELD 2-BG-22-S001-D	2.630	87.094	212.906	0.00E+00
222	WELD 2-BG-22-S001-G	2.630	86.616	213.384	0.00E+00
223	WELD 2-BG-22-F002	2.630	86.705	213.295	0.00E+00
224	WELD 2-EM-03-F016	5.190	134.476	165.524	0.00E+00
225	WELD 2-EM-03-S015-C	5.190	118.910	181.090	0.00E+00
226	WELD 2-EM-03-S015-B	5.190	113.602	186.398	0.00E+00
227	WELD 2-EM-03-F015	5.190	115.405	184.595	0.00E+00
228	WELD 2-HB-24-FW051	1.690	82.277	217.723	0.00E+00
229	WELD 2-HB-24-FW052	1.690	83.455	216.545	0.00E+00
230	WELD 2-BG-22-S001-F	1.690	83.561	216.439	0.00E+00
231	WELD 2-BB-01-S301-6	8.750	243.742	56.258	0.00E+00
232	WELD 2-BB-01-S301-3	1.690	89.223	210.777	0.00E+00
233	WELD 2-BB-01-S301-4	2.120	97.544	202.456	0.00E+00
234	WELD 2-RV-302-121-C	27.500	197.365	102.635	0.00E+00
235	WELD 2-BB-01-F302	27.500	200.530	99.470	0.00E+00
236	WELD 2-BB-01-S301-2	27.500	212.821	87.179	0.00E+00
237	WELD 2-BB-01-F301	27.500	816.971	-516.971	1.06E-08
238	WELD 2-BB-01-S302-3	5.190	136.392	163.608	0.00E+00
239	WELD 2-RV-301-121-C	29.000	294.364	5.636	0.00E+00
240	WELD 2-BB-01-F303	29.000	208.079	91.921	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
241	WELD 2-BB-01-S302-2	29.000	1076.505	-776.505	4.33E-09
242	WELD 2-BB-01-3065C-WDC-001-FW1	29.000	1089.701	-789.701	5.70E-09
243	WELD EBB01C-RSG-INLET-SC010	29.000	1089.364	-789.364	5.70E-09
244	WELD 2-BB-09-FW152	1.690	79.879	220.121	0.00E+00
245	WELD 2-BB-09-FW151	1.690	79.281	220.719	0.00E+00
246	WELD 2-BB-09-FW148	1.690	78.817	221.183	0.00E+00
247	WELD 2-BB-09-FW147	1.690	78.800	221.200	0.00E+00
248	WELD 2-BB-09-FW142	1.690	79.117	220.883	0.00E+00
249	WELD 2-BB-09-FW141	1.690	80.391	219.609	0.00E+00
250	WELD 2-BB-09-V181-2	1.690	80.376	219.624	0.00E+00
251	WELD 2-BB-09-FW153-A	1.340	79.418	220.582	0.00E+00
252	WELD 2-BB-09-FW154-A	1.340	79.875	220.125	0.00E+00
253	WELD 2-BB-04-S002-L	1.690	86.133	213.867	0.00E+00
254	WELD 2-BG-24-FW068	1.690	85.710	214.290	0.00E+00
255	WELD 2-BG-24-FW067	1.690	81.623	218.377	0.00E+00
256	WELD 2-BG-24-BB-V084-2	1.690	81.555	218.445	0.00E+00
257	WELD 2-BG-24-FW062	1.690	81.555	218.445	0.00E+00
258	WELD 2-BB-02-F006	5.190	185.924	114.076	0.00E+00
259	WELD 2-TBB03-3-C-W	5.190	185.924	114.076	0.00E+00
260	WELD 2-BB-02-S007-B	5.190	178.429	121.571	0.00E+00
261	WELD 2-BB-02-S007-D	5.190	166.355	133.645	0.00E+00
262	WELD 2-BB-02-S007-E	5.190	157.770	142.230	0.00E+00
263	WELD 2-BB-02-S007-F	5.190	158.097	141.903	0.00E+00
264	WELD 2-BB-02-S007-G	5.190	168.056	131.944	0.00E+00
265	WELD 2-BB-02-S007-J	5.190	148.931	151.069	0.00E+00
266	WELD 2-BB-02-S001-J	5.190	142.098	157.902	0.00E+00
267	WELD 2-BB-02-S001-G	5.190	157.342	142.658	0.00E+00
268	WELD 2-BB-02-S001-F	5.190	146.247	153.753	0.00E+00
269	WELD 2-BB-02-S001-E	5.190	144.827	155.173	0.00E+00
270	WELD 2-BB-02-S001-D	5.190	151.234	148.766	0.00E+00
271	WELD 2-BB-02-S001-B	5.190	164.556	135.444	0.00E+00
272	WELD 2-TBB03-3-A-W	5.190	173.530	126.470	0.00E+00
273	WELD 2-BB-02-F001	5.190	173.530	126.470	0.00E+00
274	WELD 2-TBB03-3-B-W	5.190	178.812	121.188	0.00E+00
275	WELD 2-BB-02-F005	5.190	178.812	121.188	0.00E+00
276	WELD 2-BB-02-S006-B	5.190	169.458	130.542	0.00E+00
277	WELD 2-BB-02-S006-D	5.190	156.117	143.883	0.00E+00
278	WELD 2-BB-02-S006-E	5.190	150.919	149.081	0.00E+00
279	WELD 2-BB-02-S006-F	5.190	152.860	147.140	0.00E+00
280	WELD 2-BB-02-S006-G	5.190	163.672	136.328	0.00E+00
281	WELD 2-BB-02-S006-J	5.190	150.225	149.775	0.00E+00
282	WELD 2-BB-04-F001	3.440	123.330	176.670	0.00E+00
283	WELD 2-TBB03-2-W	3.440	123.330	176.670	0.00E+00
284	WELD 2-BB-04-S001-D	3.440	104.391	195.609	0.00E+00
285	WELD 2-BB-04-S001-C	3.440	99.680	200.320	0.00E+00
286	WELD 2-BB-04-F023	3.440	98.698	201.302	0.00E+00
287	WELD 2-BB-04-F002	3.440	85.411	214.589	0.00E+00
288	WELD 2-BB-04-S002-R	3.440	85.630	214.370	0.00E+00
289	WELD 2-BB-04-S002-N	3.440	86.503	213.497	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
290	WELD 2-BB-02-F008	5.190	185.102	114.898	0.00E+00
291	WELD 2-TBB03-4-W	5.190	185.102	114.898	0.00E+00
292	WELD 2-BB-02-S009-B	5.190	169.196	130.804	0.00E+00
293	WELD 2-BB-02-S009-C	5.190	160.230	139.770	0.00E+00
294	WELD 2-BB-02-FW1	5.190	144.005	155.995	0.00E+00
295	WELD 2-BB-02-S009-E	5.190	129.324	170.676	0.00E+00
296	WELD 2-BB-02-F009	5.190	79.140	220.860	0.00E+00
297	WELD 2-BB-02-S010-B	5.190	78.970	221.030	0.00E+00
298	WELD 2-BB-02-FW2	5.190	78.970	221.030	0.00E+00
299	WELD 2-BB-02-F016	2.630	78.800	221.200	0.00E+00
300	WELD 2-BB-02-S014-B	2.630	78.800	221.200	0.00E+00
301	WELD 2-BB-02-S014-C	2.630	78.800	221.200	0.00E+00
302	WELD 2-BB-02-F017-A	2.630	78.800	221.200	0.00E+00
303	WELD 2-BB-02-F010	2.630	78.800	221.200	0.00E+00
304	WELD 2-BB-02-S010-H	2.630	78.800	221.200	0.00E+00
305	WELD 2-BB-02-S010-G	2.630	78.800	221.200	0.00E+00
306	WELD 2-BB-02-S010-F	2.630	78.800	221.200	0.00E+00
307	WELD 2-BB-02-FW25	2.630	78.800	221.200	0.00E+00
308	WELD 2-BB-02-FW3	2.630	78.800	221.200	0.00E+00
309	WELD 2-BB-04-S002-D	3.440	95.113	204.887	0.00E+00
310	WELD 2-BB-04-FW6	3.440	93.706	206.294	0.00E+00
311	WELD 2-BB-04-S002-B	3.440	93.362	206.638	0.00E+00
312	WELD 2-BB-04-F004	3.440	93.856	206.144	0.00E+00
313	WELD 2-BB-04-S002-M	5.190	94.770	205.230	0.00E+00
314	WELD 2-BB-04-S002-K	5.190	111.478	188.522	0.00E+00
315	WELD 2-BB-04-S002-J	5.190	113.678	186.322	0.00E+00
316	WELD 2-BB-04-S002-E	5.190	114.344	185.656	0.00E+00
317	WELD 2-BB-04-F003	5.190	112.317	187.683	0.00E+00
318	WELD 2-BB-04-S011-M	5.190	111.860	188.140	0.00E+00
319	WELD 2-BB-04-S011-L	5.190	113.091	186.909	0.00E+00
320	WELD 2-BB-04-S011-J	5.190	107.394	192.606	0.00E+00
321	WELD 2-BB-04-S011-H	5.190	105.697	194.303	0.00E+00
322	WELD 2-BB-04-S011-D	5.190	106.611	193.389	0.00E+00
323	WELD 2-BB-04-S011-C	3.440	91.766	208.234	0.00E+00
324	WELD 2-BB-04-FW5	3.440	90.930	209.070	0.00E+00
325	WELD 2-BB-04-S011-A	3.440	90.912	209.088	0.00E+00
326	WELD 2-BB-04-F014	3.440	91.728	208.272	0.00E+00
327	WELD 2-BB-01-S402-4	10.500	277.498	22.502	0.00E+00
328	WELD 2-BB-01-S402-3	11.190	285.791	14.209	0.00E+00
329	WELD 2-RV-301-121-D	29.000	283.377	16.623	0.00E+00
330	WELD 2-BB-01-F403	29.000	198.138	101.862	0.00E+00
331	WELD 2-BB-01-S402-2	29.000	1158.603	-858.603	7.55E-09
332	WELD 2-BB-01-3065D-WDC-001-FW1	29.000	1161.553	-861.553	9.26E-09
333	WELD EBB01D-RSG-INLET-SC010	29.000	1160.681	-860.681	9.14E-09
334	WELD 2-BB-01-S401-7	8.750	249.939	50.061	0.00E+00
335	WELD 2-BB-01-S401-3	1.690	89.216	210.784	0.00E+00
336	WELD 2-BB-01-S401-4	2.120	96.343	203.657	0.00E+00
337	WELD 2-RV-302-121-D	27.500	168.035	131.965	0.00E+00
338	WELD 2-BB-01-F402	27.500	171.998	128.002	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
339	WELD 2-BB-01-S401-2	27.500	199.459	100.541	0.00E+00
340	WELD 2-BB-01-F401	27.500	937.544	-637.544	1.42E-08
341	WELD 2-BB-15-F006	2.630	108.796	191.204	0.00E+00
342	WELD 2-BB-15-F001	2.630	110.866	189.134	0.00E+00
343	WELD 2-BB-01-S405-5	2.630	111.426	188.574	0.00E+00
344	WELD 2-BB-01-S405-6	1.690	88.263	211.737	0.00E+00
345	WELD EBB01D-RSG-OUTLET-SC010	31.000	1145.047	-845.047	1.42E-08
346	WELD 2-BB-01-3065D-WDC-002-FW2	31.000	1143.595	-843.595	1.45E-08
347	WELD 2-BB-01-F406	31.000	1133.995	-833.995	1.63E-08
348	WELD 2-BB-01-S404-3	31.000	1133.738	-833.738	1.66E-08
349	WELD 2-BB-01-F408	31.000	1083.705	-783.705	1.69E-08
350	WELD 2-BB-01-S405-4	31.000	1056.821	-756.821	1.78E-08
351	WELD 2-BB-01-F407	31.000	1004.162	-704.162	1.68E-08
352	WELD 2-EP-01-F019	8.750	200.430	99.570	0.00E+00
353	WELD 2-EP-01-S010-C	8.750	203.372	96.628	0.00E+00
354	WELD 2-EP-01-S010-D	8.750	221.023	78.977	0.00E+00
355	WELD 2-EP-01-S010-E	8.750	238.472	61.528	0.00E+00
356	WELD 2-EP-01-F020	8.750	246.097	53.903	0.00E+00
357	WELD 2-EJ-04-S016-F	5.190	134.282	165.718	0.00E+00
358	WELD 2-EJ-04-F029	5.190	139.493	160.507	0.00E+00
359	WELD 2-EM-05-S005-C	5.190	148.699	151.301	0.00E+00
360	WELD 2-EM-05-S005-B	5.190	149.990	150.010	0.00E+00
361	WELD 2-EM-05-F004	5.190	149.633	150.367	0.00E+00
362	WELD 2-EJ-04-F026	10.500	298.965	1.035	0.00E+00
363	WELD 2-EJ-04-S016-B	10.500	311.199	-11.199	0.00E+00
364	WELD 2-EJ-04-S016-C	10.500	319.269	-19.269	0.00E+00
365	WELD 2-EJ-04-S016-D	10.500	317.662	-17.662	0.00E+00
366	WELD 2-EJ-04-S016-E	10.500	341.292	-41.292	3.78E-10
367	WELD 2-EJ-04-S016-G	10.500	381.197	-81.197	2.26E-09
368	WELD 2-EJ-04-S016-H	10.500	403.966	-103.966	0.00E+00
369	WELD 2-EJ-04-F025	10.500	432.834	-132.834	8.11E-10
370	WELD 2-BB-07-FW004	1.340	79.316	220.684	0.00E+00
371	WELD 2-BB-07-FW003	1.340	79.501	220.499	0.00E+00
372	WELD 2-BB-07-FW002	1.340	79.602	220.398	0.00E+00
373	WELD 2-BB-07-FW001	1.340	80.046	219.954	0.00E+00
374	WELD 2-BB-07-FW005	1.690	80.000	220.000	0.00E+00
375	WELD 2-BB-07-FW006	1.690	79.683	220.317	0.00E+00
376	WELD 2-BB-07-FW007	1.690	79.252	220.748	0.00E+00
377	WELD 2-BB-07-FW008	1.690	78.800	221.200	0.00E+00
378	WELD 2-BB-07-FW011	1.690	78.800	221.200	0.00E+00
379	WELD 2-BB-07-FW012	1.690	78.800	221.200	0.00E+00
380	WELD 2-BB-07-FW013	1.690	78.800	221.200	0.00E+00
381	WELD 2-BB-07-FW014	1.690	78.800	221.200	0.00E+00
382	WELD 2-BB-07-FW019	1.690	78.800	221.200	0.00E+00
383	WELD 2-BB-07-FW020	1.690	78.800	221.200	0.00E+00
384	WELD 2-BB-07-FW021	1.690	78.800	221.200	0.00E+00
385	WELD 2-BB-07-FW022	1.690	78.844	221.156	0.00E+00
386	WELD 2-BB-07-FW023	1.690	78.800	221.200	0.00E+00
387	WELD 2-BB-07-FW024	1.690	78.800	221.200	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to Mean ∆CDF
388	WELD 2-BB-07-FW029	1.690	78.800	221.200	0.00E+00
389	WELD 2-BB-07-V211-2	1.690	78.800	221.200	0.00E+00
390	WELD 2-BG-21-F026	2.630	101.482	198.518	0.00E+00
391	WELD 2-BG-21-F027	2.630	105.771	194.229	0.00E+00
392	WELD 2-BB-01-S401-5	2.630	108.802	191.198	0.00E+00
393	WELD 2-BG-23-FW144	1.690	82.410	217.590	0.00E+00
394	WELD 2-BG-23-FW-3	1.690	82.535	217.465	0.00E+00
395	WELD 2-BG-23-FW-4	1.690	82.823	217.177	0.00E+00
396	WELD 2-BG-23-FW-5	1.690	82.754	217.246	0.00E+00
397	WELD 2-BG-23-FW145	1.690	81.805	218.195	0.00E+00
398	WELD 2-BG-23-FW149	1.690	82.831	217.169	0.00E+00
399	WELD 2-BG-23-FW148	1.690	82.583	217.417	0.00E+00
400	WELD 2-BG-23-FW143	1.690	82.114	217.886	0.00E+00
401	WELD 2-BG-23-A175752A-FW02	1.690	83.055	216.945	0.00E+00
402	WELD 2-BG-23-A175752A-FW01	1.690	83.653	216.347	0.00E+00
403	WELD 2-BG-23-FW138	1.690	87.995	212.005	0.00E+00
404	WELD 2-BG-22-F025	2.630	85.541	214.459	0.00E+00
405	WELD 2-BG-22-S020-A	2.630	82.407	217.593	0.00E+00
406	WELD 2-BG-22-S020-B	2.630	82.480	217.520	0.00E+00
407	WELD 2-BG-22-F026	2.630	82.558	217.442	0.00E+00
408	WELD 2-BG-23-FW150	1.690	82.563	217.437	0.00E+00
409	WELD 2-BG-23-FW151	1.690	81.904	218.096	0.00E+00
410	WELD 2-BG-23-FW152	1.690	81.580	218.420	0.00E+00
411	WELD 2-BG-23-FW153	1.690	81.534	218.466	0.00E+00
					5.40E-07

10.3 **Full Weld List for Particulate Margin**

This section contains the full weld list for particulate margin. Table 10-3 lists the weld location name, the corresponding pipe diameter (DEGB size), the amount of qualified coatings transported for a DEGB, the total particulate transported by a DEGB at each weld, and the particulate margin (the difference between the coatings debris loading threshold derived from strainer testing and the total coatings transported). Total coatings transported equals the qualified coatings transported in addition to the 4370 lbm of unqualified coatings debris transported and the 163 lbm of latent particulate debris transported for every break.

Table 10-3: Full weld list for particulate margin

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
1	WELD 2-BB-04-F005	3.44	1.337	4534.521	1265.479
2	WELD 2-BB-04-S003-D	3.44	1.139	4534.323	1265.677
3	WELD 2-BB-04-S003-C	3.44	1.306	4534.490	1265.510
4	WELD 2-BB-04-F006	3.44	1.613	4534.797	1265.203
5	WELD 2-BB-04-S004-C	3.44	1.511	4534.695	1265.305
6	WELD 2-BB-04-F007	3.44	3.837	4537.021	1262.979
7	WELD 2-BB-04-S005-D	3.44	3.407	4536.591	1263.409
8	WELD 2-BB-04-S005-C	3.44	3.031	4536.215	1263.785
9	WELD 2-BB-04-S005-B	3.44	1.574	4534.758	1265.242
10	WELD 2-BB-04-F008	3.44	1.498	4534.682	1265.318
11	WELD 2-BB-04-S006-C	3.44	2.191	4535.375	1264.625
12	WELD 2-BB-04-S006-B	3.44	1.960	4535.144	1264.856
13	WELD 2-BB-04-F009	3.44	1.169	4534.353	1265.647
14	WELD 2-BB-04-S007-F	3.44	1.146	4534.330	1265.670
15	WELD 2-BB-04-S007-E	3.44	1.507	4534.691	1265.309
16	WELD 2-BB-04-S007-D	3.44	1.291	4534.475	1265.525
17	WELD 2-BB-04-S007-B	3.44	1.204	4534.388	1265.612
18	WELD 2-BB-04-F010	3.44	1.248	4534.432	1265.568
19	WELD 2-BB-04-S008-D	3.44	1.317	4534.501	1265.499
20	WELD 2-BB-04-S008-C	3.44	1.173	4534.357	1265.643
21	WELD 2-BB-04-S008-B	3.44	1.215	4534.399	1265.601
22	WELD 2-BB-04-F011	3.44	0.872	4534.056	1265.944
23	WELD 2-BB-04-S009-D	3.44	3.356	4536.540	1263.460
24	WELD 2-BB-04-S009-C	3.44	3.007	4536.191	1263.809
25	WELD 2-BB-04-S009-B	3.44	2.991	4536.175	1263.825
26	WELD 2-BB-04-F012	3.44	3.707	4536.891	1263.109
27	WELD 2-BB-01-S101-5	3.44	5.463	4538.647	1261.353
28	WELD 2-BB-04-F015	3.44	1.291	4534.475	1265.525
29	WELD 2-BB-04-S012-F	3.44	1.082	4534.266	1265.734
30	WELD 2-BB-04-S012-E	3.44	1.036	4534.220	1265.780
31	WELD 2-BB-04-S012-D	3.44	1.699	4534.883	1265.117
32	WELD 2-BB-04-S012-C	3.44	2.021	4535.205	1264.795
33	WELD 2-BB-04-F016	3.44	1.669	4534.853	1265.147
34	WELD 2-BB-04-S013-F	3.44	1.627	4534.811	1265.189
35	WELD 2-BB-04-S013-H	3.44	2.056	4535.240	1264.760
36	WELD 2-BB-04-S013-D	3.44	2.528	4535.712	1264.288
37	WELD 2-BB-04-S013-C	3.44	2.143	4535.327	1264.673
38	WELD 2-BB-04-S013-B	3.44	1.992	4535.176	1264.824
39	WELD 2-BB-04-F017	3.44	1.978	4535.162	1264.838
40	WELD 2-BB-04-S014-E	3.44	1.597	4534.781	1265.219
41	WELD 2-BB-04-S014-D	3.44	1.599	4534.783	1265.217
42	WELD 2-BB-04-S014-C	3.44	1.548	4534.732	1265.268
43	WELD 2-BB-04-S014-B	3.44	1.568	4534.752	1265.248
44	WELD 2-BB-04-F018	3.44	1.974	4535.158	1264.842
45	WELD 2-BB-04-S015-F	3.44	2.190	4535.374	1264.626
46	WELD 2-BB-04-S015-E	3.44	1.545	4534.729	1265.271
47	WELD 2-BB-04-S015-D	3.44	1.338	4534.522	1265.478

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
48	WELD 2-BB-04-S015-B	3.44	1.204	4534.388	1265.612
49	WELD 2-BB-04-F019	3.44	1.236	4534.420	1265.580
50	WELD 2-BB-04-FW2	3.44	1.278	4534.462	1265.538
51	WELD 2-BB-04-S016-C	3.44	1.240	4534.424	1265.576
52	WELD 2-BB-04-S016-B	3.44	0.827	4534.011	1265.989
53	WELD 2-BB-04-F020	3.44	0.826	4534.010	1265.990
54	WELD 2-BB-04-S017-B	3.44	0.879	4534.063	1265.937
55	WELD 2-BB-04-F021	3.44	0.879	4534.063	1265.937
56	WELD 2-BB-04-S018-D	3.44	3.803	4536.987	1263.013
57	WELD 2-BB-04-S018-C	3.44	3.241	4536.425	1263.575
58	WELD 2-BB-04-S018-B	3.44	3.217	4536.401	1263.599
59	WELD 2-BB-04-F022	3.44	3.866	4537.050	1262.950
60	WELD 2-EM-03-BBV059-2	1.34	0.197	4533.381	1266.619
61	WELD 2-EM-03-FW225	1.34	0.177	4533.361	1266.639
62	WELD 2-EM-03-FW226	1.34	0.159	4533.343	1266.657
63	WELD 2-EM-03-FW227	1.34	0.223	4533.407	1266.593
64	WELD 2-BB-01-S401-6	2.63	2.333	4535.517	1264.483
65	WELD 2-BB-01-S401-10	2.63	2.056	4535.240	1264.760
66	WELD 2-EM-03-FW259	1.34	0.272	4533.456	1266.544
67	WELD 2-EM-03-FW258	1.34	0.175	4533.359	1266.641
68	WELD 2-EM-03-BBV040-2	1.34	0.200	4533.384	1266.616
69	WELD 2-BB-01-S301-5	2.63	2.432	4535.616	1264.384
70	WELD 2-BB-01-S301-9	2.63	2.213	4535.397	1264.603
71	WELD 2-HB-24-FW67	1.69	1.858	4535.042	1264.958
72	WELD 2-HB-24-FW66	1.69	2.355	4535.539	1264.461
73	WELD 2-HB-24-FW065	1.69	2.630	4535.814	1264.186
74	WELD 2-HB-24-FW064	1.69	0.454	4533.638	1266.362
75	WELD 2-BB-01-F004	11.19	146.870	4680.054	1119.946
76	WELD 2-TBB03-1-W	11.19	146.870	4680.054	1119.946
77	WELD 2-BB-01-S003-3	11.19	160.891	4694.075	1105.925
78	WELD 2-BB-01-S003-2	11.19	173.558	4706.742	1093.258
79	WELD 2-BB-01-S003-8	11.19	104.680	4637.864	1162.136
80	WELD 2-BB-01-F003	11.19	65.119	4598.303	1201.697
81	WELD 2-BB-01-F002	11.19	103.981	4637.165	1162.835
82	WELD 2-BB-01-S001-6	11.19	185.852	4719.036	1080.964
83	WELD 2-BB-01-F001	11.19	136.427	4669.611	1130.389
84	WELD 2-BB-01-S101-8	2.63	3.790	4536.974	1263.026
85	WELD 2-BG-21-F014	2.63	2.450	4535.634	1264.366
86	WELD 2-BG-21-FW-1	2.63	0.992	4534.176	1265.824
87	WELD 2-BG-21-S010-D	2.63	0.663	4533.847	1266.153
88	WELD 2-BG-21-S010-C	2.63	0.641	4533.825	1266.175
89	WELD 2-BG-21-S010-B	2.63	0.641	4533.825	1266.175
90	WELD 2-BG-21-S010-A	2.63	0.671	4533.855	1266.145
91	WELD 2-BG-21-F013	2.63	0.665	4533.849	1266.151
92	WELD 2-EP-02-F008	8.75	80.024	4613.208	1186.792
93	WELD 2-EP-02-S004-E	8.75	82.445	4615.629	1184.371
94	WELD 2-EP-02-FW2	8.75	84.054	4617.238	1182.762
95	WELD 2-EP-02-S004-C	8.75	88.810	4621.994	1178.006
96	WELD 2-EP-02-F007	8.75	91.318	4624.502	1175.498

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
97	WELD 2-EM-03-F012	5.19	13.658	4546.842	1253.158
98	WELD 2-EM-03-S012-D	5.19	12.190	4545.374	1254.626
99	WELD 2-EM-03-S012-B	5.19	10.478	4543.662	1256.338
100	WELD 2-EM-03-W237498-FW03	5.19	10.288	4543.472	1256.528
101	WELD 2-BB-11-C600739-FW01	1.34	0.456	4533.640	1266.360
102	WELD 2-BB-11-A600739B-FW01	1.34	0.609	4533.793	1266.207
103	WELD 2-BB-11-FW008	1.69	1.066	4534.250	1265.750
104	WELD 2-BB-11-FW011	1.69	0.916	4534.100	1265.900
105	WELD 2-BB-11-FW012	1.69	0.370	4533.554	1266.446
106	WELD 2-BB-11-FW013	1.69	0.331	4533.515	1266.485
107	WELD 2-BB-11-FW014	1.69	0.223	4533.407	1266.593
108	WELD 2-BB-11-FW015	1.69	0.229	4533.413	1266.587
109	WELD 2-BB-11-FW016	1.69	0.267	4533.451	1266.549
110	WELD 2-BB-11-V151-2	1.69	0.225	4533.409	1266.591
111	WELD 2-EM-03-FW269	1.34	0.233	4533.417	1266.583
112	WELD 2-EM-03-FW268	1.34	0.198	4533.382	1266.618
113	WELD 2-EM-03-BBV022-2	1.34	0.229	4533.413	1266.587
114	WELD 2-BB-01-S201-8	2.63	2.377	4535.561	1264.439
115	WELD 2-BB-01-S201-15	2.63	2.091	4535.275	1264.725
116	WELD 2-BB-06-F006	2.63	1.617	4534.801	1265.199
117	WELD 2-BB-06-F001	2.63	1.925	4535.109	1264.891
118	WELD 2-BB-01-S205-5	2.63	2.182	4535.366	1264.634
119	WELD 2-BB-01-S205-6	1.69	1.367	4534.551	1265.449
120	WELD EBB01B-RSG-OUTLET-SC010	31.00	863.064	5396.248	403.752
121	WELD 2-BB-01-3065B-WDC-002-FW2	31.00	862.174	5395.358	404.642
122	WELD 2-BB-01-F206	31.00	857.335	5390.519	409.481
123	WELD 2-BB-01-S204-3	31.00	873.352	5406.536	393.464
124	WELD 2-BB-01-F208	31.00	771.879	5305.063	494.937
125	WELD 2-BB-01-S205-4	31.00	745.361	5278.545	521.455
126	WELD 2-BB-01-F207	31.00	723.804	5256.988	543.012
127	WELD 2-BB-01-S201-7	8.75	67.006	4600.190	1199.810
128	WELD 2-BB-01-S201-3	1.69	1.004	4534.188	1265.812
129	WELD 2-BB-01-S201-4	2.12	1.676	4534.860	1265.140
130	WELD 2-BB-01-S201-5	3.44	6.064	4539.248	1260.752
131	WELD 2-RV-302-121-B	27.50	114.031	4647.215	1152.785
132	WELD 2-BB-01-F202	27.50	121.993	4655.177	1144.823
133	WELD 2-BB-01-S201-2	27.50	161.492	4694.676	1105.324
134	WELD 2-BB-01-F201	27.50	628.465	5161.649	638.351
135	WELD 2-BB-01-S202-3	5.19	13.999	4547.183	1252.817
136	WELD 2-RV-301-121-B	29.00	131.720	4664.904	1135.096
137	WELD 2-BB-01-F203	29.00	123.855	4657.039	1142.961
138	WELD 2-BB-01-S202-2	29.00	877.715	5410.899	389.101
139	WELD 2-BB-01-3065B-WDC-001-FW1	29.00	838.508	5371.692	428.308
140	WELD EBB01B-RSG-INLET-SC010	29.00	836.287	5369.471	430.529
141	WELD 2-EM-03-FW235	1.34	0.262	4533.446	1266.554
142	WELD 2-EM-03-FW234	1.34	0.145	4533.329	1266.671
143	WELD 2-EM-03-BBV001-2	1.34	0.167	4533.351	1266.649
144	WELD 2-BB-01-S101-9	2.63	2.438	4535.622	1264.378
145	WELD 2-BB-01-S101-13	2.63	2.100	4535.284	1264.716

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
146	WELD 2-EJ-04-F030	10.50	77.399	4610.583	1189.417
147	WELD 2-EJ-04-FW9	10.50	59.661	4592.845	1207.155
148	WELD 2-EJ-04-S018-C	10.50	57.228	4590.412	1209.588
149	WELD 2-EJ-04-FW8	10.50	57.434	4590.618	1209.382
150	WELD 2-EJ-04-S018-E	10.50	56.417	4589.601	1210.399
151	WELD 2-EJ-04-F031	10.50	72.458	4605.642	1194.358
152	WELD 2-BB-08-FW041-A-R-1	1.69	1.485	4534.669	1265.331
153	WELD 2-BB-08-FW099	1.69	1.557	4534.741	1265.259
154	WELD 2-BB-08-FW044	1.69	1.654	4534.838	1265.162
155	WELD 2-BB-08-FW045	1.69	1.546	4534.730	1265.270
156	WELD 2-BB-08-FW046-A	1.69	1.659	4534.843	1265.157
157	WELD 2-BB-08-FW047	1.69	2.103	4535.287	1264.713
158	WELD 2-BB-08-FW052-B	1.69	2.136	4535.320	1264.680
159	WELD 2-BB-08-FW053	1.69	2.360	4535.544	1264.456
160	WELD 2-BB-08-V121-2	1.69	1.463	4534.647	1265.353
161	WELD 2-BB-08-FW039	1.34	0.095	4533.279	1266.721
162	WELD 2-BB-08-FW040	1.34	0.963	4534.147	1265.853
163	WELD 2-BB-05-F006	2.63	1.823	4535.007	1264.993
164	WELD 2-BB-05-F001	2.63	1.961	4535.145	1264.855
165	WELD 2-BB-01-S105-5	2.63	2.141	4535.325	1264.675
166	WELD 2-BB-01-S105-6	1.69	1.384	4534.568	1265.432
167	WELD EBB01A-RSG-OUTLET-SC010	31.00	972.513	5505.697	294.303
168	WELD 2-BB-01-3065A-WDC-002-FW2	31.00	970.928	5504.112	295.888
169	WELD 2-BB-01-F106	31.00	964.310	5497.494	302.506
170	WELD 2-BB-01-S104-3	31.00	979.205	5512.389	287.611
171	WELD 2-BB-01-F108	31.00	841.940	5375.124	424.876
172	WELD 2-BB-01-S105-4	31.00	780.156	5313.340	486.660
173	WELD 2-BB-01-F107	31.00	745.974	5279.158	520.842
174	WELD 2-BB-01-S102-3	10.50	84.016	4617.200	1182.800
175	WELD 2-RV-301-121-A	29.00	131.684	4664.868	1135.132
176	WELD 2-BB-01-F103	29.00	123.256	4656.440	1143.560
177	WELD 2-BB-01-S102-2	29.00	1039.934	5573.118	226.882
178	WELD 2-BB-01-3065A-WDC-001-FW1	29.00	995.956	5529.140	270.860
179	WELD EBB01A-RSG-INLET-SC010	29.00	992.453	5525.637	274.363
180	WELD 2-BB-01-S101-7	8.75	66.120	4599.304	1200.696
181	WELD 2-BB-01-S101-3	1.69	1.053	4534.237	1265.763
182	WELD 2-RV-302-121-A	27.50	117.349	4650.533	1149.467
183	WELD 2-BB-01-F102	27.50	125.438	4658.622	1141.378
184	WELD 2-BB-01-S101-2	27.50	168.924	4702.108	1097.892
185	WELD 2-BB-01-F101	27.50	656.028	5189.212	610.788
186	WELD 2-HB-24-FW001	1.69	1.847	4535.031	1264.969
187	WELD 2-HB-24-FW002	1.69	2.344	4535.528	1264.472
188	WELD 2-HB-24-FW078	1.69	2.505	4535.689	1264.311
189	WELD 2-HB-24-FW079-A	1.69	0.262	4533.446	1266.554
190	WELD 2-EP-01-F008	8.75	73.834	4607.018	1192.982
191	WELD 2-EP-01-S004-E	8.75	74.946	4608.130	1191.870
192	WELD 2-EP-01-S004-D	8.75	76.740	4609.924	1190.076
193	WELD 2-EP-01-S004-C	8.75	82.667	4615.851	1184.149
194	WELD 2-EP-01-F007	8.75	85.849	4619.033	1180.967

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
195	WELD 2-EJ-04-S018-F	5.19	13.557	4546.741	1253.259
196	WELD 2-EM-05-F007	5.19	13.105	4546.289	1253.711
197	WELD 2-EM-05-S007-D	5.19	12.432	4545.616	1254.384
198	WELD 2-EM-05-S007-C	5.19	9.979	4543.163	1256.837
199	WELD 2-EM-05-W566538-F006	5.19	7.946	4541.130	1258.870
200	WELD 2-BB-01-S102-6	2.12	1.553	4534.737	1265.263
201	WELD 2-BB-14-F006	2.63	1.638	4534.822	1265.178
202	WELD 2-BB-14-F001	2.63	1.948	4535.132	1264.868
203	WELD 2-BB-01-S305-5	2.63	2.147	4535.331	1264.669
204	WELD 2-BB-01-S305-6	2.63	5.550	4538.734	1261.266
205	WELD EBB01C-RSG-OUTLET-SC010	31.00	772.101	5305.285	494.715
206	WELD 2-BB-01-3065C-WDC-002-FW2	31.00	770.606	5303.790	496.210
207	WELD 2-BB-01-F306	31.00	768.948	5302.132	497.868
208	WELD 2-BB-01-S304-3	31.00	800.728	5333.912	466.088
209	WELD 2-BB-01-F308	31.00	701.494	5234.678	565.322
210	WELD 2-BB-01-S305-4	31.00	676.103	5209.287	590.713
211	WELD 2-BB-01-F307	31.00	638.551	5171.735	628.265
212	WELD 2-EP-02-F019	8.75	71.414	4604.598	1195.402
213	WELD 2-EP-02-S009-E	8.75	72.982	4606.166	1193.834
214	WELD 2-EP-02-S009-D	8.75	72.835	4606.019	1193.981
215	WELD 2-EP-02-S009-C	8.75	75.826	4609.010	1190.990
216	WELD 2-EP-02-F018	8.75	53.180	4586.364	1213.636
217	WELD 2-BG-22-F001	2.63	5.739	4538.923	1261.077
218	WELD 2-BG-22-S001-A	2.63	6.104	4539.288	1260.712
219	WELD 2-BG-22-S001-B	2.63	1.393	4534.577	1265.423
220	WELD 2-BG-22-S001-C	2.63	1.031	4534.215	1265.785
221	WELD 2-BG-22-S001-D	2.63	0.874	4534.058	1265.942
222	WELD 2-BG-22-S001-G	2.63	0.863	4534.047	1265.953
223	WELD 2-BG-22-F002	2.63	0.612	4533.796	1266.204
224	WELD 2-EM-03-F016	5.19	11.421	4544.605	1255.395
225	WELD 2-EM-03-S015-C	5.19	7.317	4540.501	1259.499
226	WELD 2-EM-03-S015-B	5.19	8.829	4542.013	1257.987
227	WELD 2-EM-03-F015	5.19	9.881	4543.065	1256.935
228	WELD 2-HB-24-FW051	1.69	0.374	4533.558	1266.442
229	WELD 2-HB-24-FW052	1.69	0.482	4533.666	1266.334
230	WELD 2-BG-22-S001-F	1.69	0.444	4533.628	1266.372
231	WELD 2-BB-01-S301-6	8.75	62.496	4595.680	1204.320
232	WELD 2-BB-01-S301-3	1.69	1.011	4534.195	1265.805
233	WELD 2-BB-01-S301-4	2.12	1.620	4534.804	1265.196
234	WELD 2-RV-302-121-C	27.50	62.992	4596.176	1203.824
235	WELD 2-BB-01-F302	27.50	69.604	4602.788	1197.212
236	WELD 2-BB-01-S301-2	27.50	85.250	4618.434	1181.566
237	WELD 2-BB-01-F301	27.50	581.819	5115.003	684.997
238	WELD 2-BB-01-S302-3	5.19	10.822	4544.006	1255.994
239	WELD 2-RV-301-121-C	29.00	125.830	4659.014	1140.986
240	WELD 2-BB-01-F303	29.00	116.506	4649.690	1150.310
241	WELD 2-BB-01-S302-2	29.00	819.713	5352.897	447.103
242	WELD 2-BB-01-3065C-WDC-001-FW1	29.00	785.996	5319.180	480.820
243	WELD EBB01C-RSG-INLET-SC010	29.00	783.949	5317.133	482.867

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
244	WELD 2-BB-09-FW152	1.69	0.178	4533.362	1266.638
245	WELD 2-BB-09-FW151	1.69	0.214	4533.398	1266.602
246	WELD 2-BB-09-FW148	1.69	0.232	4533.416	1266.584
247	WELD 2-BB-09-FW147	1.69	0.232	4533.416	1266.584
248	WELD 2-BB-09-FW142	1.69	0.218	4533.402	1266.598
249	WELD 2-BB-09-FW141	1.69	0.286	4533.470	1266.530
250	WELD 2-BB-09-V181-2	1.69	0.211	4533.395	1266.605
251	WELD 2-BB-09-FW153-A	1.34	0.139	4533.323	1266.677
252	WELD 2-BB-09-FW154-A	1.34	0.100	4533.284	1266.716
253	WELD 2-BB-04-S002-L	1.69	1.078	4534.262	1265.738
254	WELD 2-BG-24-FW068	1.69	1.417	4534.601	1265.399
255	WELD 2-BG-24-FW067	1.69	0.271	4533.455	1266.545
256	WELD 2-BG-24-BB-V084-2	1.69	0.231	4533.415	1266.585
257	WELD 2-BG-24-FW062	1.69	0.231	4533.415	1266.585
258	WELD 2-BB-02-F006	5.19	6.802	4539.986	1260.014
259	WELD 2-TBB03-3-C-W	5.19	6.802	4539.986	1260.014
260	WELD 2-BB-02-S007-B	5.19	6.547	4539.731	1260.269
261	WELD 2-BB-02-S007-D	5.19	6.126	4539.310	1260.690
262	WELD 2-BB-02-S007-E	5.19	5.783	4538.967	1261.033
263	WELD 2-BB-02-S007-F	5.19	7.589	4540.773	1259.227
264	WELD 2-BB-02-S007-G	5.19	16.931	4550.115	1249.885
265	WELD 2-BB-02-S007-J	5.19	16.092	4549.276	1250.724
266	WELD 2-BB-02-S001-J	5.19	14.319	4547.503	1252.497
267	WELD 2-BB-02-S001-G	5.19	11.546	4544.730	1255.270
268	WELD 2-BB-02-S001-F	5.19	4.797	4537.981	1262.019
269	WELD 2-BB-02-S001-E	5.19	2.560	4535.744	1264.256
270	WELD 2-BB-02-S001-D	5.19	2.086	4535.270	1264.730
271	WELD 2-BB-02-S001-B	5.19	2.118	4535.302	1264.698
272	WELD 2-TBB03-3-A-W	5.19	2.628	4535.812	1264.188
273	WELD 2-BB-02-F001	5.19	2.628	4535.812	1264.188
274	WELD 2-TBB03-3-B-W	5.19	3.036	4536.220	1263.780
275	WELD 2-BB-02-F005	5.19	3.036	4536.220	1263.780
276	WELD 2-BB-02-S006-B	5.19	2.533	4535.717	1264.283
277	WELD 2-BB-02-S006-D	5.19	2.140	4535.324	1264.676
278	WELD 2-BB-02-S006-E	5.19	3.464	4536.648	1263.352
279	WELD 2-BB-02-S006-F	5.19	5.876	4539.060	1260.940
280	WELD 2-BB-02-S006-G	5.19	15.778	4548.962	1251.038
281	WELD 2-BB-02-S006-J	5.19	16.048	4549.232	1250.768
282	WELD 2-BB-04-F001	3.44	0.572	4533.756	1266.244
283	WELD 2-TBB03-2-W	3.44	0.572	4533.756	1266.244
284	WELD 2-BB-04-S001-D	3.44	0.687	4533.871	1266.129
285	WELD 2-BB-04-S001-C	3.44	0.825	4534.009	1265.991
286	WELD 2-BB-04-F023	3.44	0.950	4534.134	1265.866
287	WELD 2-BB-04-F002	3.44	0.977	4534.161	1265.839
288	WELD 2-BB-04-S002-R	3.44	0.989	4534.173	1265.827
289	WELD 2-BB-04-S002-N	3.44	1.292	4534.476	1265.524
290	WELD 2-BB-02-F008	5.19	5.281	4538.465	1261.535
291	WELD 2-TBB03-4-W	5.19	5.281	4538.465	1261.535
292	WELD 2-BB-02-S009-B	5.19	5.000	4538.184	1261.816

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
293	WELD 2-BB-02-S009-C	5.19	4.832	4538.016	1261.984
294	WELD 2-BB-02-FW1	5.19	4.228	4537.412	1262.588
295	WELD 2-BB-02-S009-E	5.19	2.946	4536.130	1263.870
296	WELD 2-BB-02-F009	5.19	4.190	4537.374	1262.626
297	WELD 2-BB-02-S010-B	5.19	3.468	4536.652	1263.348
298	WELD 2-BB-02-FW2	5.19	3.359	4536.543	1263.457
299	WELD 2-BB-02-F016	2.63	1.130	4534.314	1265.686
300	WELD 2-BB-02-S014-B	2.63	0.489	4533.673	1266.327
301	WELD 2-BB-02-S014-C	2.63	0.479	4533.663	1266.337
302	WELD 2-BB-02-F017-A	2.63	0.597	4533.781	1266.219
303	WELD 2-BB-02-F010	2.63	0.551	4533.735	1266.265
304	WELD 2-BB-02-S010-H	2.63	0.474	4533.658	1266.342
305	WELD 2-BB-02-S010-G	2.63	0.482	4533.666	1266.334
306	WELD 2-BB-02-S010-F	2.63	0.852	4534.036	1265.964
307	WELD 2-BB-02-FW25	2.63	0.594	4533.778	1266.222
308	WELD 2-BB-02-FW3	2.63	0.990	4534.174	1265.826
309	WELD 2-BB-04-S002-D	3.44	1.542	4534.726	1265.274
310	WELD 2-BB-04-FW6	3.44	1.391	4534.575	1265.425
311	WELD 2-BB-04-S002-B	3.44	1.370	4534.554	1265.446
312	WELD 2-BB-04-F004	3.44	1.626	4534.810	1265.190
313	WELD 2-BB-04-S002-M	5.19	4.454	4537.638	1262.362
314	WELD 2-BB-04-S002-K	5.19	47.749	4580.933	1219.067
315	WELD 2-BB-04-S002-J	5.19	45.291	4578.475	1221.525
316	WELD 2-BB-04-S002-E	5.19	15.577	4548.761	1251.239
317	WELD 2-BB-04-F003	5.19	46.819	4580.003	1219.997
318	WELD 2-BB-04-S011-M	5.19	45.736	4578.920	1221.080
319	WELD 2-BB-04-S011-L	5.19	38.807	4571.991	1228.009
320	WELD 2-BB-04-S011-J	5.19	4.467	4537.651	1262.349
321	WELD 2-BB-04-S011-H	5.19	3.119	4536.303	1263.697
322	WELD 2-BB-04-S011-D	5.19	3.040	4536.224	1263.776
323	WELD 2-BB-04-S011-C	3.44	1.240	4534.424	1265.576
324	WELD 2-BB-04-FW5	3.44	1.123	4534.307	1265.693
325	WELD 2-BB-04-S011-A	3.44	1.136	4534.320	1265.680
326	WELD 2-BB-04-F014	3.44	1.169	4534.353	1265.647
327	WELD 2-BB-01-S402-4	10.50	86.547	4619.731	1180.269
328	WELD 2-BB-01-S402-3	11.19	125.406	4658.590	1141.410
329	WELD 2-RV-301-121-D	29.00	125.324	4658.508	1141.492
330	WELD 2-BB-01-F403	29.00	116.127	4649.311	1150.689
331	WELD 2-BB-01-S402-2	29.00	1032.108	5565.292	234.708
332	WELD 2-BB-01-3065D-WDC-001-FW1	29.00	1004.506	5537.690	262.310
333	WELD EBB01D-RSG-INLET-SC010	29.00	1002.198	5535.382	264.618
334	WELD 2-BB-01-S401-7	8.75	62.584	4595.768	1204.232
335	WELD 2-BB-01-S401-3	1.69	1.027	4534.211	1265.789
336	WELD 2-BB-01-S401-4	2.12	1.658	4534.842	1265.158
337	WELD 2-RV-302-121-D	27.50	62.282	4595.466	1204.534
338	WELD 2-BB-01-F402	27.50	67.804	4600.988	1199.012
339	WELD 2-BB-01-S401-2	27.50	84.482	4617.666	1182.334
340	WELD 2-BB-01-F401	27.50	769.705	5302.889	497.111
341	WELD 2-BB-15-F006	2.63	2.250	4535.434	1264.566

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
342	WELD 2-BB-15-F001	2.63	2.274	4535.458	1264.542
343	WELD 2-BB-01-S405-5	2.63	2.351	4535.535	1264.465
344	WELD 2-BB-01-S405-6	1.69	1.368	4534.552	1265.448
345	WELD EBB01D-RSG-OUTLET-SC010	31.00	1016.714	5549.898	250.102
346	WELD 2-BB-01-3065D-WDC-002-FW2	31.00	1016.794	5549.978	250.022
347	WELD 2-BB-01-F406	31.00	1015.553	5548.737	251.263
348	WELD 2-BB-01-S404-3	31.00	1020.436	5553.620	246.380
349	WELD 2-BB-01-F408	31.00	956.658	5489.842	310.158
350	WELD 2-BB-01-S405-4	31.00	888.856	5422.040	377.960
351	WELD 2-BB-01-F407	31.00	873.405	5406.589	393.411
352	WELD 2-EP-01-F019	8.75	57.528	4590.712	1209.288
353	WELD 2-EP-01-S010-C	8.75	101.538	4634.722	1165.278
354	WELD 2-EP-01-S010-D	8.75	87.944	4621.128	1178.872
355	WELD 2-EP-01-S010-E	8.75	82.721	4615.905	1184.095
356	WELD 2-EP-01-F020	8.75	76.369	4609.553	1190.447
357	WELD 2-EJ-04-S016-F	5.19	23.383	4556.567	1243.433
358	WELD 2-EJ-04-F029	5.19	25.022	4558.206	1241.794
359	WELD 2-EM-05-S005-C	5.19	22.924	4556.108	1243.892
360	WELD 2-EM-05-S005-B	5.19	19.624	4552.808	1247.192
361	WELD 2-EM-05-F004	5.19	17.310	4550.494	1249.506
362	WELD 2-EJ-04-F026	10.50	80.907	4614.091	1185.909
363	WELD 2-EJ-04-S016-B	10.50	78.882	4612.066	1187.934
364	WELD 2-EJ-04-S016-C	10.50	76.562	4609.746	1190.254
365	WELD 2-EJ-04-S016-D	10.50	76.914	4610.098	1189.902
366	WELD 2-EJ-04-S016-E	10.50	69.639	4602.823	1197.177
367	WELD 2-EJ-04-S016-G	10.50	72.057	4605.241	1194.759
368	WELD 2-EJ-04-S016-H	10.50	80.408	4613.592	1186.408
369	WELD 2-EJ-04-F025	10.50	95.112	4628.296	1171.704
370	WELD 2-BB-07-FW004	1.34	0.732	4533.916	1266.084
371	WELD 2-BB-07-FW003	1.34	0.642	4533.826	1266.174
372	WELD 2-BB-07-FW002	1.34	0.561	4533.745	1266.255
373	WELD 2-BB-07-FW001	1.34	0.288	4533.472	1266.528
374	WELD 2-BB-07-FW005	1.69	1.359	4534.543	1265.457
375	WELD 2-BB-07-FW006	1.69	1.327	4534.511	1265.489
376	WELD 2-BB-07-FW007	1.69	1.403	4534.587	1265.413
377	WELD 2-BB-07-FW008	1.69	1.175	4534.359	1265.641
378	WELD 2-BB-07-FW011	1.69	1.028	4534.212	1265.788
379	WELD 2-BB-07-FW012	1.69	0.722	4533.906	1266.094
380	WELD 2-BB-07-FW013	1.69	0.484	4533.668	1266.332
381	WELD 2-BB-07-FW014	1.69	0.198	4533.382	1266.618
382	WELD 2-BB-07-FW019	1.69	0.198	4533.382	1266.618
383	WELD 2-BB-07-FW020	1.69	0.223	4533.407	1266.593
384	WELD 2-BB-07-FW021	1.69	0.220	4533.404	1266.596
385	WELD 2-BB-07-FW022	1.69	3.491	4536.675	1263.325
386	WELD 2-BB-07-FW023	1.69	3.643	4536.827	1263.173
387	WELD 2-BB-07-FW024	1.69	2.783	4535.967	1264.033
388	WELD 2-BB-07-FW029	1.69	1.772	4534.956	1265.044
389	WELD 2-BB-07-V211-2	1.69	1.312	4534.496	1265.504
390	WELD 2-BG-21-F026	2.63	1.584	4534.768	1265.232

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Qualified Coatings Transported at DEGB Size (lbm)	Total Particulate Transported at DEGB Size (lbm)	Particulate Margin (lbm)
391	WELD 2-BG-21-F027	2.63	2.030	4535.214	1264.786
392	WELD 2-BB-01-S401-5	2.63	2.692	4535.876	1264.124
393	WELD 2-BG-23-FW144	1.69	0.299	4533.483	1266.517
394	WELD 2-BG-23-FW-3	1.69	0.329	4533.513	1266.487
395	WELD 2-BG-23-FW-4	1.69	0.419	4533.603	1266.397
396	WELD 2-BG-23-FW-5	1.69	0.389	4533.573	1266.427
397	WELD 2-BG-23-FW145	1.69	0.238	4533.422	1266.578
398	WELD 2-BG-23-FW149	1.69	0.411	4533.595	1266.405
399	WELD 2-BG-23-FW148	1.69	0.410	4533.594	1266.406
400	WELD 2-BG-23-FW143	1.69	0.399	4533.583	1266.417
401	WELD 2-BG-23-A175752A-FW02	1.69	0.472	4533.656	1266.344
402	WELD 2-BG-23-A175752A-FW01	1.69	0.663	4533.847	1266.153
403	WELD 2-BG-23-FW138	1.69	1.858	4535.042	1264.958
404	WELD 2-BG-22-F025	2.63	0.480	4533.664	1266.336
405	WELD 2-BG-22-S020-A	2.63	0.483	4533.667	1266.333
406	WELD 2-BG-22-S020-B	2.63	0.482	4533.666	1266.334
407	WELD 2-BG-22-F026	2.63	0.570	4533.754	1266.246
408	WELD 2-BG-23-FW150	1.69	0.338	4533.522	1266.478
409	WELD 2-BG-23-FW151	1.69	0.277	4533.461	1266.539
410	WELD 2-BG-23-FW152	1.69	0.262	4533.446	1266.554
411	WELD 2-BG-23-FW153	1.69	0.294	4533.478	1266.522

10.4 **Full Isolable Weld List**

This section contains the full weld list for isolable welds. Table 10-4 lists the weld location name, the corresponding pipe diameter (DEGB size), the amount of fiber transported by a DEGB, the fiber margin (the difference between the RoverD failure threshold and the amount of fiber transported), and the 25-year ΔCDF contributions for each isolable weld before and after applying the isolation valve failure probability. All per weld contributions to ΔCDF are based on geometric aggregation and the 25-year NUREG-1829 frequencies at the smallest critical break size. Welds that do not exceed the RoverD limit for a DEGB are not deemed critical welds, have a negative difference from threshold (i.e., positive fiber margin), and do not contribute to mean ΔCDF. Note that the per weld contributions to ΔCDF in the last two columns sum to the mean ΔCDF values reported for isolable welds reported in Table 8-1.

Table 10-4: Full isolable weld list

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to GM ΔCDF (Unweighted)	Contribution to GM ΔCDF (Weighted)
1	AFIVWELD 2-HB-24-FW063	1.690	80.627	219.373	0.00E+00	0.00E+00
2	AFIVWELD 2-HB-24-FW062	1.690	80.163	219.837	0.00E+00	0.00E+00
3	AFIVWELD 2-BG-21-F012	2.630	83.157	216.843	0.00E+00	0.00E+00
4	AFIVWELD 2-BG-21-S009-B	2.630	82.887	217.113	0.00E+00	0.00E+00
5	AFIVWELD 2-BG-21-S009-A	2.630	82.773	217.227	0.00E+00	0.00E+00
6	AFIVWELD 2-BG-21-F011	2.630	82.939	217.061	0.00E+00	0.00E+00
7	AFIVWELD 2-BB-11-V151-1	1.690	79.806	220.194	0.00E+00	0.00E+00
8	AFIVWELD 2-BB-11-FW017	1.690	79.811	220.189	0.00E+00	0.00E+00
9	AFIVWELD 2-BB-11-V150-2	1.690	79.979	220.021	0.00E+00	0.00E+00
10	AFIVWELD 2-BB-08-V121-1	1.690	78.800	221.200	0.00E+00	0.00E+00
11	AFIVWELD 2-BB-08-FW054	1.690	78.800	221.200	0.00E+00	0.00E+00
12	AFIVWELD 2-BB-08-V120-2	1.690	78.800	221.200	0.00E+00	0.00E+00
13	AFIVWELD 2-EM-05-FW099	1.690	85.923	214.077	0.00E+00	0.00E+00
14	AFIVWELD 2-EM-05-FW098	1.690	85.497	214.503	0.00E+00	0.00E+00
15	AFIVWELD 2-EM-05-FW109	1.690	85.595	214.405	0.00E+00	0.00E+00
16	AFIVWELD 2-EM-05-FW9	1.690	82.485	217.515	0.00E+00	0.00E+00
17	AFIVWELD 2-EM-05-BB8949E-2	1.690	81.029	218.971	0.00E+00	0.00E+00
18	AFIVWELD 2-HB-24-FW080	1.690	80.706	219.294	0.00E+00	0.00E+00
19	AFIVWELD 2-HB-24-FW081	1.690	80.550	219.450	0.00E+00	0.00E+00
20	AFIVWELD 2-HB-24-FW083-C	1.690	80.428	219.572	0.00E+00	0.00E+00
21	AFIVWELD 2-HB-24-FW084	1.690	80.217	219.783	0.00E+00	0.00E+00
22	AFIVWELD 2-EM-05-W566538-F005	5.190	132.252	167.748	0.00E+00	0.00E+00
23	AFIVWELD 2-EM-05-S006-B	5.190	141.226	158.774	0.00E+00	0.00E+00
24	AFIVWELD 2-HB-24-FW049	1.690	80.380	219.620	0.00E+00	0.00E+00
25	AFIVWELD 2-HB-24-FW050	1.690	81.838	218.162	0.00E+00	0.00E+00
26	AFIVWELD 2-BB-09-V181-1	1.690	81.302	218.698	0.00E+00	0.00E+00
27	AFIVWELD 2-BB-09-FW140	1.690	82.534	217.466	0.00E+00	0.00E+00
28	AFIVWELD 2-BB-09-V180-2	1.690	84.171	215.829	0.00E+00	0.00E+00
29	AFIVWELD 2-BB-02-F018-A	2.630	78.800	221.200	0.00E+00	0.00E+00
30	AFIVWELD 2-BB-02-F019	2.630	78.800	221.200	0.00E+00	0.00E+00
31	AFIVWELD 2-BB-02-F012	2.630	78.800	221.200	0.00E+00	0.00E+00
32	AFIVWELD 2-BB-02-F011	2.630	78.800	221.200	0.00E+00	0.00E+00
33	AFIVWELD 2-BB-07-V211-1	1.690	78.800	221.200	0.00E+00	0.00E+00
34	AFIVWELD 2-BB-07-FW030	1.690	78.800	221.200	0.00E+00	0.00E+00
35	AFIVWELD 2-BB-07-V210-2	1.690	78.800	221.200	0.00E+00	0.00E+00
36	AFIVWELD 2-BG-21-F024	2.630	87.894	212.106	0.00E+00	0.00E+00
37	AFIVWELD 2-BG-21-S019-A	2.630	91.176	208.824	0.00E+00	0.00E+00
38	AFIVWELD 2-BG-21-S019-B	2.630	91.133	208.867	0.00E+00	0.00E+00
39	AFIVWELD 2-BG-21-S019-C	2.630	87.151	212.849	0.00E+00	0.00E+00
40	AFIVWELD 2-BG-21-S019-D	2.630	88.893	211.107	0.00E+00	0.00E+00
41	AFIVWELD 2-BG-21-F025	2.630	93.327	206.673	0.00E+00	0.00E+00
42	AFIVWELD 2-BG-23-FW146	1.690	80.983	219.017	0.00E+00	0.00E+00
43	AFIVWELD 2-BG-23-FW147	1.690	80.205	219.795	0.00E+00	0.00E+00
44	AFIVWELD 2-BG-22-F027	2.630	82.499	217.501	0.00E+00	0.00E+00
45	AFIVWELD 2-BG-22-F028	2.630	82.860	217.140	0.00E+00	0.00E+00
46	AFIVWELD 2-BG-24-FW061	1.690	81.139	218.861	0.00E+00	0.00E+00
47	AFIVWELD 2-BG-24-BB-V084-1	1.690	81.139	218.861	0.00E+00	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to GM ΔCDF (Unweighted)	Contribution to GM ΔCDF (Weighted)
48	AFIVWELD 2-EP-02-8818B-1	5.190	93.514	206.486	0.00E+00	0.00E+00
49	AFIVWELD 2-EP-01-8818A-1	5.190	98.998	201.002	0.00E+00	0.00E+00
50	AFIVWELD 2-EJ-04-F032	10.500	436.815	-136.815	2.17E-09	2.41E-12
51	AFIVWELD 2-EJ-04-S019-D	10.500	409.533	-109.533	4.78E-10	5.30E-13
52	AFIVWELD 2-EJ-04-FW7	10.500	408.380	-108.380	3.21E-09	3.56E-12
53	AFIVWELD 2-EJ-04-S019-F	10.500	416.886	-116.886	3.86E-09	4.28E-12
54	AFIVWELD 2-EJ-04-F033	10.500	410.195	-110.195	0.00E+00	0.00E+00
55	AFIVWELD 2-EJ-04-F034	10.500	224.764	75.236	0.00E+00	0.00E+00
56	AFIVWELD 2-EJ-04-S037-A	10.500	212.222	87.778	0.00E+00	0.00E+00
57	AFIVWELD 2-EJ-04-S037-B	10.500	167.932	132.068	0.00E+00	0.00E+00
58	AFIVWELD 2-EJ-04-S037-C	10.500	163.056	136.944	0.00E+00	0.00E+00
59	AFIVWELD 2-EJ-04-F048	10.500	163.933	136.067	0.00E+00	0.00E+00
60	AFIVWELD 2-EP-02-8818C-1	5.190	100.117	199.883	0.00E+00	0.00E+00
61	AFIVWELD 2-EJ-04-S015-E	10.500	372.189	-72.189	0.00E+00	0.00E+00
62	AFIVWELD 2-EJ-04-S015-C	10.500	181.500	118.500	0.00E+00	0.00E+00
63	AFIVWELD 2-EJ-04-F023	10.500	180.166	119.834	0.00E+00	0.00E+00
64	AFIVWELD 2-EJ-04-S014-C	10.500	178.584	121.416	0.00E+00	0.00E+00
65	AFIVWELD 2-EJ-04-S014-D	10.500	168.162	131.838	0.00E+00	0.00E+00
66	AFIVWELD 2-EJ-04-F022	10.500	168.542	131.458	0.00E+00	0.00E+00
67	AFIVWELD 2-EJ-04-S013-B	10.500	169.887	130.113	0.00E+00	0.00E+00
68	AFIVWELD 2-EJ-04-F021	10.500	173.843	126.157	0.00E+00	0.00E+00
69	AFIVWELD 2-EJ-04-F024	10.500	452.401	-152.401	1.57E-09	1.74E-12
70	AFIVWELD 2-EP-01-8818D-1	5.190	105.762	194.238	0.00E+00	0.00E+00
71	AFIVWELD 2-EM-03-S003-F	1.340	81.439	218.561	0.00E+00	0.00E+00
72	AFIVWELD 2-EM-03-FW270	1.340	81.369	218.631	0.00E+00	0.00E+00
73	AFIVWELD 2-EM-03-FW271	1.340	80.203	219.797	0.00E+00	0.00E+00
74	AFIVWELD 2-EM-03-FW207	1.340	80.180	219.820	0.00E+00	0.00E+00
75	AFIVWELD 2-EM-03-FW208	1.340	80.215	219.785	0.00E+00	0.00E+00
76	AFIVWELD 2-EM-03-FW209	1.340	80.216	219.784	0.00E+00	0.00E+00
77	AFIVWELD 2-EM-03-FW210	1.340	80.593	219.407	0.00E+00	0.00E+00
78	AFIVWELD 2-EM-03-FW215	1.340	80.184	219.816	0.00E+00	0.00E+00
79	AFIVWELD 2-EM-03-FW078	1.340	80.873	219.127	0.00E+00	0.00E+00
80	AFIVWELD 2-EM-03-FW079	1.340	80.521	219.479	0.00E+00	0.00E+00
81	AFIVWELD 2-EM-03-FW216	1.340	80.843	219.157	0.00E+00	0.00E+00
82	AFIVWELD 2-EM-03-FW221	1.340	80.774	219.226	0.00E+00	0.00E+00
83	AFIVWELD 2-EM-03-FW222	1.340	80.202	219.798	0.00E+00	0.00E+00
84	AFIVWELD 2-EM-03-FW082	1.340	80.059	219.941	0.00E+00	0.00E+00
85	AFIVWELD 2-EM-03-FW223	1.340	80.389	219.611	0.00E+00	0.00E+00
86	AFIVWELD 2-EM-03-FW224	1.340	81.712	218.288	0.00E+00	0.00E+00
87	AFIVWELD 2-EM-03-BBV059-1	1.340	81.497	218.503	0.00E+00	0.00E+00
88	AFIVWELD 2-EM-03-BBV040-1	1.340	80.312	219.688	0.00E+00	0.00E+00
89	AFIVWELD 2-EM-03-FW257	1.340	80.376	219.624	0.00E+00	0.00E+00
90	AFIVWELD 2-EM-03-FW256	1.340	80.464	219.536	0.00E+00	0.00E+00
91	AFIVWELD 2-EM-03-FW251	1.340	80.384	219.616	0.00E+00	0.00E+00
92	AFIVWELD 2-EM-03-FW250	1.340	81.119	218.881	0.00E+00	0.00E+00
93	AFIVWELD 2-EM-03-FW115	1.340	80.146	219.854	0.00E+00	0.00E+00
94	AFIVWELD 2-EM-03-FW114	1.340	80.146	219.854	0.00E+00	0.00E+00
95	AFIVWELD 2-EM-03-FW113	1.340	81.507	218.493	0.00E+00	0.00E+00
96	AFIVWELD 2-EM-03-FW249	1.340	80.031	219.969	0.00E+00	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to GM ΔCDF (Unweighted)	Contribution to GM ΔCDF (Weighted)
97	AFIVWELD 2-EM-03-FW248	1.340	80.408	219.592	0.00E+00	0.00E+00
98	AFIVWELD 2-EM-03-FW243	1.340	80.910	219.090	0.00E+00	0.00E+00
99	AFIVWELD 2-EM-03-FW242	1.340	80.298	219.702	0.00E+00	0.00E+00
100	AFIVWELD 2-EM-03-FW241	1.340	80.310	219.690	0.00E+00	0.00E+00
101	AFIVWELD 2-EM-03-FW240	1.340	80.257	219.743	0.00E+00	0.00E+00
102	AFIVWELD 2-EM-03-FW275	1.340	80.249	219.751	0.00E+00	0.00E+00
103	AFIVWELD 2-EM-03-FW274	1.340	81.796	218.204	0.00E+00	0.00E+00
104	AFIVWELD 2-EM-03-S003-N	1.340	81.752	218.248	0.00E+00	0.00E+00
105	AFIVWELD 2-EM-03-S003-P	2.630	85.017	214.983	0.00E+00	0.00E+00
106	AFIVWELD 2-EM-03-S003-M	2.630	84.807	215.193	0.00E+00	0.00E+00
107	AFIVWELD 2-EM-03-S003-L	2.630	84.325	215.675	0.00E+00	0.00E+00
108	AFIVWELD 2-EM-03-S003-K	2.630	83.630	216.370	0.00E+00	0.00E+00
109	AFIVWELD 2-EM-03-S003-J	2.630	83.303	216.697	0.00E+00	0.00E+00
110	AFIVWELD 2-EM-03-FW2	2.630	83.580	216.420	0.00E+00	0.00E+00
111	AFIVWELD 2-EM-03-S003-D	2.630	83.566	216.434	0.00E+00	0.00E+00
112	AFIVWELD 2-EM-03-S003-B	2.630	84.012	215.988	0.00E+00	0.00E+00
113	AFIVWELD 2-EM-03-F003	2.630	83.623	216.377	0.00E+00	0.00E+00
114	AFIVWELD 2-EM-03-FW3	2.630	82.484	217.516	0.00E+00	0.00E+00
115	AFIVWELD 2-EM-03-F002	2.630	82.217	217.783	0.00E+00	0.00E+00
116	AFIVWELD 2-EM-03-W237498-FW02	5.190	116.051	183.949	0.00E+00	0.00E+00
117	AFIVWELD 2-EM-03-W237498-FW01	5.190	111.016	188.984	0.00E+00	0.00E+00
118	AFIVWELD 2-EM-03-S011-G	5.190	108.669	191.331	0.00E+00	0.00E+00
119	AFIVWELD 2-EM-03-S011-F	5.190	108.464	191.536	0.00E+00	0.00E+00
120	AFIVWELD 2-EM-03-S011-D	5.190	109.302	190.698	0.00E+00	0.00E+00
121	AFIVWELD 2-EM-03-S011-C	5.190	109.925	190.075	0.00E+00	0.00E+00
122	AFIVWELD 2-EM-03-FW-1	5.190	118.067	181.933	0.00E+00	0.00E+00
123	AFIVWELD 2-EM-03-S011-B	5.190	113.535	186.465	0.00E+00	0.00E+00
124	AFIVWELD 2-EM-03-F009	5.190	110.808	189.192	0.00E+00	0.00E+00
125	AFIVWELD 2-EJ-04-F014	5.190	93.713	206.287	0.00E+00	0.00E+00
126	AFIVWELD 2-EM-03-S013-B	1.690	84.422	215.578	0.00E+00	0.00E+00
127	AFIVWELD 2-EM-03-FW170	1.690	84.671	215.329	0.00E+00	0.00E+00
128	AFIVWELD 2-EM-03-FW169	1.690	80.745	219.255	0.00E+00	0.00E+00
129	AFIVWELD 2-EM-03-FW353	1.690	81.668	218.332	0.00E+00	0.00E+00
130	AFIVWELD 2-EM-03-FW352	1.690	81.820	218.180	0.00E+00	0.00E+00
131	AFIVWELD 2-EM-03-FW351	1.690	82.051	217.949	0.00E+00	0.00E+00
132	AFIVWELD 2-EM-03-FW345	1.690	81.976	218.024	0.00E+00	0.00E+00
133	AFIVWELD 2-EM-03-FW344	1.690	80.768	219.232	0.00E+00	0.00E+00
134	AFIVWELD 2-EM-03-V002-2	1.690	80.495	219.505	0.00E+00	0.00E+00
135	AFIVWELD 2-EM-03-S010-B	1.690	84.392	215.608	0.00E+00	0.00E+00
136	AFIVWELD 2-EM-03-FW153	1.690	84.572	215.428	0.00E+00	0.00E+00
137	AFIVWELD 2-EM-03-FW321	1.690	81.514	218.486	0.00E+00	0.00E+00
138	AFIVWELD 2-EM-03-FW320	1.690	81.599	218.401	0.00E+00	0.00E+00
139	AFIVWELD 2-EM-03-FW319	1.690	81.432	218.568	0.00E+00	0.00E+00
140	AFIVWELD 2-EM-03-FW313	1.690	81.238	218.762	0.00E+00	0.00E+00
141	AFIVWELD 2-EM-03-FW312	1.690	80.477	219.523	0.00E+00	0.00E+00
142	AFIVWELD 2-EM-03-V001-2	1.690	80.281	219.719	0.00E+00	0.00E+00
143	AFIVWELD 2-EM-03-BBV022-1	1.340	81.121	218.879	0.00E+00	0.00E+00
144	AFIVWELD 2-EM-03-FW267	1.340	81.161	218.839	0.00E+00	0.00E+00
145	AFIVWELD 2-EM-03-FW266	1.340	81.375	218.625	0.00E+00	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to GM ΔCDF (Unweighted)	Contribution to GM ΔCDF (Weighted)
146	AFIVWELD 2-EM-03-FW265	1.340	81.614	218.386	0.00E+00	0.00E+00
147	AFIVWELD 2-EM-03-FW264	1.340	80.310	219.690	0.00E+00	0.00E+00
148	AFIVWELD 2-EM-03-FW263	1.340	80.309	219.691	0.00E+00	0.00E+00
149	AFIVWELD 2-EM-03-FW262	1.340	80.257	219.743	0.00E+00	0.00E+00
150	AFIVWELD 2-EM-03-FW261	1.340	80.197	219.803	0.00E+00	0.00E+00
151	AFIVWELD 2-EM-03-FW260	1.340	81.526	218.474	0.00E+00	0.00E+00
152	AFIVWELD 2-EM-03-BBV001-1	1.340	80.794	219.206	0.00E+00	0.00E+00
153	AFIVWELD 2-EM-03-FW233	1.340	80.873	219.127	0.00E+00	0.00E+00
154	AFIVWELD 2-EM-03-FW232	1.340	80.794	219.206	0.00E+00	0.00E+00
155	AFIVWELD 2-EM-03-FW094	1.340	80.674	219.326	0.00E+00	0.00E+00
156	AFIVWELD 2-EM-03-FW231	1.340	80.233	219.767	0.00E+00	0.00E+00
157	AFIVWELD 2-EM-03-FW230	1.340	80.224	219.776	0.00E+00	0.00E+00
158	AFIVWELD 2-EM-03-FW229	1.340	80.223	219.777	0.00E+00	0.00E+00
159	AFIVWELD 2-EM-03-FW228	1.340	80.180	219.820	0.00E+00	0.00E+00
160	AFIVWELD 2-EM-03-FW273	1.340	80.434	219.566	0.00E+00	0.00E+00
161	AFIVWELD 2-EM-03-FW272	1.340	81.430	218.570	0.00E+00	0.00E+00
162	AFIVWELD 2-EM-03-S003-G	1.340	81.439	218.561	0.00E+00	0.00E+00
163	AFIVWELD 2-EM-05-BB8949E-1	1.690	80.833	219.167	0.00E+00	0.00E+00
164	AFIVWELD 2-EM-05-FW086	1.690	80.728	219.272	0.00E+00	0.00E+00
165	AFIVWELD 2-EM-05-FW084	1.690	81.505	218.495	0.00E+00	0.00E+00
166	AFIVWELD 2-EM-05-FW083	1.690	81.639	218.361	0.00E+00	0.00E+00
167	AFIVWELD 2-EM-05-FW082	1.690	81.187	218.813	0.00E+00	0.00E+00
168	AFIVWELD 2-EM-05-FW076	1.690	81.067	218.933	0.00E+00	0.00E+00
169	AFIVWELD 2-EM-05-FW075	1.690	80.695	219.305	0.00E+00	0.00E+00
170	AFIVWELD 2-EM-05-V003-2	1.690	80.574	219.426	0.00E+00	0.00E+00
171	AFIVWELD 2-EM-03-F014	5.190	113.299	186.701	0.00E+00	0.00E+00
172	AFIVWELD 2-EM-03-FW5	5.190	108.657	191.343	0.00E+00	0.00E+00
173	AFIVWELD 2-EM-03-S014-C	5.190	111.498	188.502	0.00E+00	0.00E+00
174	AFIVWELD 2-EM-03-FW4	5.190	121.945	178.055	0.00E+00	0.00E+00
175	AFIVWELD 2-EM-03-F013	5.190	117.736	182.264	0.00E+00	0.00E+00
176	AFIVWELD 2-EJ-04-F017	5.190	92.631	207.369	0.00E+00	0.00E+00
177	AFIVWELD 2-EM-05-FW005	1.690	81.684	218.316	0.00E+00	0.00E+00
178	AFIVWELD 2-EM-05-FW006	1.690	80.848	219.152	0.00E+00	0.00E+00
179	AFIVWELD 2-EM-05-FW007	1.690	80.730	219.270	0.00E+00	0.00E+00
180	AFIVWELD 2-EM-05-FW008	1.690	81.077	218.923	0.00E+00	0.00E+00
181	AFIVWELD 2-EM-05-FW013	1.690	81.187	218.813	0.00E+00	0.00E+00
182	AFIVWELD 2-EM-05-FW016	1.690	82.547	217.453	0.00E+00	0.00E+00
183	AFIVWELD 2-EM-05-FW017	1.690	82.482	217.518	0.00E+00	0.00E+00
184	AFIVWELD 2-EM-05-FW018	1.690	82.596	217.404	0.00E+00	0.00E+00
185	AFIVWELD 2-EM-05-FW024	1.690	82.614	217.386	0.00E+00	0.00E+00
186	AFIVWELD 2-EM-05-FW025	1.690	82.297	217.703	0.00E+00	0.00E+00
187	AFIVWELD 2-EM-05-V004-2	1.690	82.124	217.876	0.00E+00	0.00E+00
188	AFIVWELD 2-EM-05-F003	5.190	151.639	148.361	0.00E+00	0.00E+00
189	AFIVWELD 2-EM-05-S004-B	5.190	154.985	145.015	0.00E+00	0.00E+00
190	AFIVWELD 2-EP-02-F006	8.750	216.123	83.877	0.00E+00	0.00E+00
191	AFIVWELD 2-EP-02-S003-M	8.750	210.728	89.272	0.00E+00	0.00E+00
192	AFIVWELD 2-EP-02-S003-L	8.750	214.921	85.079	0.00E+00	0.00E+00
193	AFIVWELD 2-EP-02-S003-J	8.750	265.551	34.449	0.00E+00	0.00E+00
194	AFIVWELD 2-EP-02-S003-H	8.750	265.445	34.555	0.00E+00	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to GM ∆CDF (Unweighted)	Contribution to GM ∆CDF (Weighted)
195	AFIVWELD 2-EP-02-S003-G	8.750	248.277	51.723	0.00E+00	0.00E+00
196	AFIVWELD 2-EP-02-S003-F	8.750	236.195	63.805	0.00E+00	0.00E+00
197	AFIVWELD 2-EP-02-S003-E	8.750	208.442	91.558	0.00E+00	0.00E+00
198	AFIVWELD 2-EP-02-S003-D	8.750	201.957	98.043	0.00E+00	0.00E+00
199	AFIVWELD 2-EP-02-F005	8.750	189.919	110.081	0.00E+00	0.00E+00
200	AFIVWELD 2-EP-02-8818B-2	5.190	94.490	205.510	0.00E+00	0.00E+00
201	AFIVWELD 2-EP-02-3066B-WDC-001-FW1	5.190	94.759	205.241	0.00E+00	0.00E+00
202	AFIVWELD 2-EP-02-S005-G	5.190	98.671	201.329	0.00E+00	0.00E+00
203	AFIVWELD 2-EP-02-FW4	5.190	114.274	185.726	0.00E+00	0.00E+00
204	AFIVWELD 2-EP-02-FW3	5.190	115.926	184.074	0.00E+00	0.00E+00
205	AFIVWELD 2-EP-02-S005-D	5.190	125.110	174.890	0.00E+00	0.00E+00
206	AFIVWELD 2-EP-02-F009	5.190	139.905	160.095	0.00E+00	0.00E+00
207	AFIVWELD 2-EP-02-V020-2	1.690	81.896	218.104	0.00E+00	0.00E+00
208	AFIVWELD 2-EP-02-FW010	1.690	81.983	218.017	0.00E+00	0.00E+00
209	AFIVWELD 2-EP-02-FW009	1.690	82.089	217.911	0.00E+00	0.00E+00
210	AFIVWELD 2-EP-02-FW008	1.690	82.024	217.976	0.00E+00	0.00E+00
211	AFIVWELD 2-EP-02-FW007	1.690	81.907	218.093	0.00E+00	0.00E+00
212	AFIVWELD 2-EP-02-FW006	1.690	81.770	218.230	0.00E+00	0.00E+00
213	AFIVWELD 2-EP-02-FW005	1.690	84.146	215.854	0.00E+00	0.00E+00
214	AFIVWELD 2-EP-02-S005-B	1.690	83.910	216.090	0.00E+00	0.00E+00
215	AFIVWELD 2-EP-01-F012	5.190	142.220	157.780	0.00E+00	0.00E+00
216	AFIVWELD 2-EP-01-S006-B	5.190	128.887	171.113	0.00E+00	0.00E+00
217	AFIVWELD 2-EP-01-F011	5.190	119.445	180.555	0.00E+00	0.00E+00
218	AFIVWELD 2-EP-01-FW5	5.190	100.343	199.657	0.00E+00	0.00E+00
219	AFIVWELD 2-EP-01-S005-E	5.190	99.674	200.326	0.00E+00	0.00E+00
220	AFIVWELD 2-EP-01-S005-D	5.190	99.791	200.209	0.00E+00	0.00E+00
221	AFIVWELD 2-EP-01-S005-C	5.190	95.510	204.490	0.00E+00	0.00E+00
222	AFIVWELD 2-EP-01-S005-B	5.190	95.640	204.360	0.00E+00	0.00E+00
223	AFIVWELD 2-EP-01-3066A-WDC-002-FW2	5.190	97.279	202.721	0.00E+00	0.00E+00
224	AFIVWELD 2-EP-01-3066A-WDC-003-FW3	5.190	98.251	201.749	0.00E+00	0.00E+00
225	AFIVWELD 2-EP-01-8818A-2	5.190	98.388	201.612	0.00E+00	0.00E+00
226	AFIVWELD 2-EP-01-F006	8.750	218.262	81.738	0.00E+00	0.00E+00
227	AFIVWELD 2-EP-01-S003-L	8.750	212.093	87.907	0.00E+00	0.00E+00
228	AFIVWELD 2-EP-01-FW3	8.750	214.413	85.587	0.00E+00	0.00E+00
229	AFIVWELD 2-EP-01-S003-H	8.750	262.348	37.652	0.00E+00	0.00E+00
230	AFIVWELD 2-EP-01-S003-G	8.750	260.829	39.171	0.00E+00	0.00E+00
231	AFIVWELD 2-EP-01-S003-F	8.750	266.997	33.003	0.00E+00	0.00E+00
232	AFIVWELD 2-EP-01-S003-E	8.750	256.198	43.802	0.00E+00	0.00E+00
233	AFIVWELD 2-EP-01-S003-D	8.750	225.784	74.216	0.00E+00	0.00E+00
234	AFIVWELD 2-EP-01-S003-C	8.750	220.440	79.560	0.00E+00	0.00E+00
235	AFIVWELD 2-EP-01-F005	8.750	221.448	78.552	0.00E+00	0.00E+00
236	AFIVWELD 2-EP-01-S005-F	1.690	85.121	214.879	0.00E+00	0.00E+00
237	AFIVWELD 2-EP-01-FW049	1.690	84.776	215.224	0.00E+00	0.00E+00
238	AFIVWELD 2-EP-01-FW050	1.690	82.431	217.569	0.00E+00	0.00E+00
239	AFIVWELD 2-EP-01-FW051	1.690	82.083	217.917	0.00E+00	0.00E+00
240	AFIVWELD 2-EP-01-FW052	1.690	81.865	218.135	0.00E+00	0.00E+00
241	AFIVWELD 2-EP-01-FW053	1.690	81.572	218.428	0.00E+00	0.00E+00
242	AFIVWELD 2-EP-01-FW054	1.690	81.422	218.578	0.00E+00	0.00E+00
243	AFIVWELD 2-EP-01-FW055	1.690	81.407	218.593	0.00E+00	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to GM ∆CDF (Unweighted)	Contribution to GM ∆CDF (Weighted)
244	AFIVWELD 2-EP-01-FW056	1.690	81.792	218.208	0.00E+00	0.00E+00
245	AFIVWELD 2-EP-01-FW059	1.690	81.993	218.007	0.00E+00	0.00E+00
246	AFIVWELD 2-EP-01-V010-2	1.690	80.286	219.714	0.00E+00	0.00E+00
247	AFIVWELD 2-EP-01-FW060	1.690	80.286	219.714	0.00E+00	0.00E+00
248	AFIVWELD 2-EP-02-F017	8.750	191.849	108.151	0.00E+00	0.00E+00
249	AFIVWELD 2-EP-02-S008-K	8.750	172.035	127.965	0.00E+00	0.00E+00
250	AFIVWELD 2-EP-02-S008-J	8.750	167.027	132.973	0.00E+00	0.00E+00
251	AFIVWELD 2-EP-02-S008-H	8.750	203.197	96.803	0.00E+00	0.00E+00
252	AFIVWELD 2-EP-02-S008-G	8.750	213.213	86.787	0.00E+00	0.00E+00
253	AFIVWELD 2-EP-02-S008-F	8.750	223.119	76.881	0.00E+00	0.00E+00
254	AFIVWELD 2-EP-02-S008-D	8.750	230.384	69.616	0.00E+00	0.00E+00
255	AFIVWELD 2-EP-02-F016	8.750	224.572	75.428	0.00E+00	0.00E+00
256	AFIVWELD 2-EP-02-V030-2	1.690	81.668	218.332	0.00E+00	0.00E+00
257	AFIVWELD 2-EP-02-FW027	1.690	81.710	218.290	0.00E+00	0.00E+00
258	AFIVWELD 2-EP-02-FW026	1.690	81.707	218.293	0.00E+00	0.00E+00
259	AFIVWELD 2-EP-02-FW025	1.690	81.788	218.212	0.00E+00	0.00E+00
260	AFIVWELD 2-EP-02-FW024	1.690	84.290	215.710	0.00E+00	0.00E+00
261	AFIVWELD 2-EP-02-S010-B	1.690	83.900	216.100	0.00E+00	0.00E+00
262	AFIVWELD 2-EP-02-8818C-2	5.190	98.980	201.020	0.00E+00	0.00E+00
263	AFIVWELD 2-EP-02-3066C-WDC-001-FW1	5.190	98.644	201.356	0.00E+00	0.00E+00
264	AFIVWELD 2-EP-02-FW5	5.190	122.358	177.642	0.00E+00	0.00E+00
265	AFIVWELD 2-EP-02-F020	5.190	125.332	174.668	0.00E+00	0.00E+00
266	AFIVWELD 2-EP-01-F018	8.750	182.311	117.689	0.00E+00	0.00E+00
267	AFIVWELD 2-EP-01-S013-E	8.750	175.616	124.384	0.00E+00	0.00E+00
268	AFIVWELD 2-EP-01-S013-D	8.750	186.079	113.921	0.00E+00	0.00E+00
269	AFIVWELD 2-EP-01-S013-C	8.750	203.790	96.210	0.00E+00	0.00E+00
270	AFIVWELD 2-EP-01-S013-B	8.750	208.781	91.219	0.00E+00	0.00E+00
271	AFIVWELD 2-EP-01-F017	8.750	210.468	89.532	0.00E+00	0.00E+00
272	AFIVWELD 2-EP-01-V040-2	1.690	81.472	218.528	0.00E+00	0.00E+00
273	AFIVWELD 2-EP-01-FW048	1.690	81.654	218.346	0.00E+00	0.00E+00
274	AFIVWELD 2-EP-01-FW047	1.690	85.714	214.286	0.00E+00	0.00E+00
275	AFIVWELD 2-EP-01-FW046	1.690	85.512	214.488	0.00E+00	0.00E+00
276	AFIVWELD 2-EP-01-S011-J	1.690	84.606	215.394	0.00E+00	0.00E+00
277	AFIVWELD 2-EP-01-S013-K	5.190	112.329	187.671	0.00E+00	0.00E+00
278	AFIVWELD 2-EP-01-S013-J	5.190	111.497	188.503	0.00E+00	0.00E+00
279	AFIVWELD 2-EP-01-F024	5.190	112.355	187.645	0.00E+00	0.00E+00
280	AFIVWELD 2-EP-01-FW4	5.190	115.749	184.251	0.00E+00	0.00E+00
281	AFIVWELD 2-EP-01-S012-H	5.190	114.042	185.958	0.00E+00	0.00E+00
282	AFIVWELD 2-EP-01-S012-F	5.190	111.530	188.470	0.00E+00	0.00E+00
283	AFIVWELD 2-EP-01-S012-E	5.190	112.045	187.955	0.00E+00	0.00E+00
284	AFIVWELD 2-EP-01-S012-D	5.190	114.238	185.762	0.00E+00	0.00E+00
285	AFIVWELD 2-EP-01-S012-C	5.190	116.698	183.302	0.00E+00	0.00E+00
286	AFIVWELD 2-EP-01-S012-B	5.190	120.477	179.523	0.00E+00	0.00E+00
287	AFIVWELD 2-EP-01-F023	5.190	121.196	178.804	0.00E+00	0.00E+00
288	AFIVWELD 2-EP-01-S011-F	5.190	121.864	178.136	0.00E+00	0.00E+00
289	AFIVWELD 2-EP-01-S011-D	5.190	113.157	186.843	0.00E+00	0.00E+00
290	AFIVWELD 2-EP-01-S011-C	5.190	112.769	187.231	0.00E+00	0.00E+00
291	AFIVWELD 2-EP-01-3066D-WDC-002-FW2	5.190	110.719	189.281	0.00E+00	0.00E+00
292	AFIVWELD 2-EP-01-3066D-WDC-003-FW3	5.190	108.694	191.306	0.00E+00	0.00E+00

#	Weld Location Name	DEGB Inside Diameter Size (inches)	Fiber Transported at DEGB Size (lbm)	Fiber Margin (lbm)	Contribution to GM ΔCDF (Unweighted)	Contribution to GM ΔCDF (Weighted)
293	AFIVWELD 2-EP-01-8818D-2	5.190	107.601	192.399	0.00E+00	0.00E+00
					1.13E-08	**1.25E-11**

11 References

[1] Regulatory Guide 1.174 "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," Revision 3, January 2018 (ADAMS Accession No. ML17317A256)"

[2] NEI 04-07 Volume 1, Pressurized Water Reactor Sump Performance Evaluation Methodology, Revision 0: Nuclear Energy Institute, December 2004.

[3] NEI 04-07 Volume 2, Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Letter 2004-02, Revision 0: Nuclear Energy Institute, December 2004.

[4] ALION-REP-ALION-2806-01, Insulation Debris Size Distribution for use in GSI-191 Resolution, Revision 4, May 19, 2009.

[5] NUREG 1829, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process," Nuclear Regulatory Commission, 2008.

[6] ALION-REP-CEC-9143-014 Revision 0, "GSI-191 Risk Aggregation Methodology Report," Alion Science and Technology, 2018.

[7] MEMO-9143-WMC-2K17-01 Revision 0, "MSLB MFLB Conditional Sump Failure Probabilities," Alion Science and Technology, 2017.

[8] NOC-AE-15003241, STP Piloted Risk-informed Approach to Ciosure for GS1-191, 2015.

Attachment 3-4

Defense-In-Depth and Safety Margin

1 Introduction

The defense-in-depth (DID) and safety margin (SM) evaluation applies for all debris effects addressed in the risk-informed element of the Callaway risk over deterministic (RoverD) methodology described in Attachment 3-3. That scope is generally described as breaks larger than approximately 9-inch breaks in reactor coolant system (RCS) primary loop piping and the pressurizer surge line where debris can be generated and transported to the sump strainers in excess of plant-specific tests. Sixty weld locations transport debris to the sump strainers in excess of plant-specific tests.

DID evaluations show that there is adequate system capability to provide assurance that public health and safety are protected in the event there is a loss-of-coolant accident (LOCA) that threatens strainer performance. It identifies operator actions that can be taken to mitigate the event and the robustness of the containment design.

SM evaluations identify margins and conservatisms in the design, analysis, and construction of the engineered safety features. Evaluations credit very low susceptibility of the welds to degradation mechanisms that could lead to a LOCA, expected smaller actual amount of debris that would be generated and transported to the sump, little or no actual contribution to head loss from chemical effects, and margin in head loss evaluations.

The conclusion of the evaluation is that substantial defense-in-depth and safety margin exists.

2 Defense-in-Depth

DID for Callaway Unit 1 is based on the plant design, operating procedures, and administrative controls. In responses to Nuclear Regulatory Commission (NRC) Bulletin 2003-01 and Generic Letter (GL) 2004-02, Callaway described modifications to plant hardware (most notably new advanced design recirculation strainers), and operating procedures and administrative controls that were implemented to address GL 2004-02 concerns. Callaway operating procedures have actions that prevent and mitigate strainer blockage based on indications available to operators such as instrumentation to monitor core water levels, sump water levels, and containment temperatures. Actions include initiation of core flush (combined cold leg and hot leg injection), which provides an alternate flow path that bypasses core inlet blockage, and refilling the refueling water storage tank (RWST), which allows temporary termination of recirculation and a return to injection mode of operation. Callaway surveillance procedures implement Technical Specification (TS) requirements for cleanliness in accessible areas of the reactor containment building to verify no loose debris (rags, trash, clothing, etc.) is present which could be transported to the sump strainers during a LOCA. Also, visual inspections of the recirculation strainer to verify inlets are not restricted by debris and that the strainer components show no evidence of structural distress or abnormal corrosion are conducted.

The current licensing basis for the containment emergency sump strainer installed to address GL 2004-02 consists of the current assumptions, initial conditions, and conclusions of GL 2004-02 related evaluations, including the current evaluations of design basis accident debris generation and transport, recirculation strainer performance, impact of chemical effects, and downstream effects of debris. Substantial plant-specific testing that supports assumptions and corresponding conclusions contained in the GL 2004-02 evaluations for Callaway was performed. This information supporting the previous deterministic methodology for demonstrating compliance is documented in supplemental information provided in response to GL 2004-02 and forms the deterministic basis for the Callaway simplified risk-informed (RI) methodology. RI elements of the analyses associated with the proposed exemption and license amendment along with the design, procedure, and administrative controls already incorporated demonstrate that the risk from LOCAs where the containment emergency sump strainer will not perform its required functions is very small and acceptable in accordance with the criteria of Regulatory Guide (RG) 1.174. The Callaway RI approach follows RG 1.174, verifying DID and SM are maintained through design modifications, ongoing design modification controls, and maintenance procedures including the in-service inspection (ISI) program. The approach is comprehensive in nature, analyzing a full spectrum of LOCAs including double-ended guillotine breaks (DEGB) for all piping sizes up to and including the largest pipe in the RCS. By requiring that mitigative capability be maintained in a realistic and RI evaluation of GL 2004-02 for a full spectrum of LOCAs, the approach ensures that DID is maintained.

The proposed change to the licensing basis is consistent with maintaining DID in that the following aspects of the facility design and operation are maintained:

- Functional requirements and design configurations of systems
- Existing plant barriers to the release of fission products
- Design provisions for redundancy, diversity, and independence
- Plant response to transients and other initiating events
- Preventative and mitigative capability of plant design features.

Based on the results of the risk-informed method and the hardware, operating procedures and administrative controls already implemented to address GL 2004-02 concerns, Callaway has high confidence that plant systems and operators would respond as required to mitigate postulated LOCAs. This confidence is bolstered by the DID features for Callaway described below.

2.1 Effectiveness of Defense-in-Depth Actions

The effectiveness of DID actions is shown to be acceptable when considering the following:

- Callaway Emergency-Operating Procedures (EOPs) are based on the approved industry standard Emergency Response Guidelines (ERGs). These symptom-based EOPs have generic or site–specific analyses that support them.
- Callaway Severe Accident Mitigation Guidelines (SAMGs) are based on approved industry standard guidance.
- Procedures are trained upon and evaluated as part of the training.
- DID actions are trained upon using the simulator to demonstrate effectiveness.
- Procedures that make framework for DID actions are evaluated during the Callaway station review and approval process.

2.2 Evaluations

Callaway DID measures that are associated with the concerns of GL 2004-02 are evaluated by applying regulatory guidance and industry guidance.

2.2.1 Guidance in RG 1.174

Callaway proposes a licensing basis change to use a risk-informed approach to address the concerns of GL 2004-02 with respect to maintaining long term cooling post–LOCA on the basis that the change meets the principles and acceptance guidelines of RG 1.174. As discussed below, DID elements given in Section 2.1.1 of RG 1.174 have been evaluated to show that the proposed change is consistent with DID for Callaway. DID is based on hardware, operating procedures, and administrative controls and design modifications that have been implemented or planned to address the concerns of GL 2004-02. The proposed licensing basis change does not propose any additional DID measures.

A reasonable balance is preserved among prevention of core damage, prevention of containment failure, and consequence mitigation.

Callaway has two trains of emergency core cooling system (ECCS) equipment for the prevention of core damage. Each train includes a high head centrifugal charging pump (CCP), an intermediate head safety injection (SI) pump, and a low head residual heat removal (RHR) pump that is routed through the RHR heat exchanger for cooling by component cooling water (CCW). Each primary cooling loop has an accumulator. Also, there are two independent trains of equipment for containment heat removal to prevent containment failure. The heat removal equipment for each train includes a Containment Spray (CS) pump and two containment air cooler (CAC) units per train that are cooled by safety-related essential service water (ESW) during an event. Consequence mitigation is achieved using active equipment of these Engineered Safety Features and by maintaining the containment building as an effective barrier to radioactive release.

The proposed license change does not involve any change to the design or design requirements of the current plant equipment associated with GL 2004-02. As discussed further below, the proposed change does not affect the containment integrity or the capability of the independent and safety-related CACs to remove post-LOCA decay heat from containment. There is no change to the strategies for the prevention of core damage, for prevention of containment failure, or for consequence mitigation. Thus, the existing balance among these is preserved.

Over-reliance on programmatic activities as compensatory measures associated with the change in the licensing basis is avoided.

Programmatic activities associated with the proposed change include the ISI program, plant personnel training, RCS leak detection program, and containment cleanliness inspection activities. The ISI program requires non-destructive examinations of the RCS components and piping. The in-service testing (IST) program requires testing of active components such as pumps and valves in the RCS, ECCS, and containment spray systems (CSS). The proposed change does not rely heavily on programmatic activities as compensatory measures nor propose any new programmatic activities that could be heavily relied upon. The risk-informed approach does consider pipe break frequencies. Callaway has previously implemented a risk-informed ISI program that was approved by the NRC. The ISI program is an effective element of DID that performs an important role in the prevention of pipe breaks. It is important to note that the risk-informed GL 2004-02 program and the risk-informed ISI program are complementary in that the risk insights from the stations plant-specific probabilistic risk assessment (PRA) are used in conjunction with deterministic information to improve the safety and effectiveness of the ISI program.

The leak detection program at Callaway is capable of early identification of RCS leakage in accordance with RG 1.45 to provide time for appropriate operator action before a flaw causing a leak would propagate to a break. This program is an important contributor to DID.

Containment cleanliness inspection activities are performed prior to reactor startup following outages, as required by the TS. The deterministic element of the GL 2004-02 program uses an input for the assumed amount of latent debris inside containment after the cleanup activity is complete that is in accordance with the Nuclear Energy Institute (NEI) 04-07 guidance for a deterministic approach. Thus, there is no over-reliance on programmatic activities to quantify or manage latent debris as compensatory measures for the risk-informed approach.

System redundancy, independence, and diversity are preserved commensurate with the expected frequency, consequences of challenges to the system, and uncertainties (for example, no risk outliers).

Callaway has two trains of ECCS equipment for the prevention of core damage. Each train includes a high head CCP, an intermediate head SI pump, and a low head RHR pump that is routed through the RHR heat exchanger for cooling by CCW. There are two independent trains of equipment for containment heat removal to prevent containment failure. The heat removal equipment for each train includes a CS pump and two CAC units per train that are cooled by safety-related ESW during and event. Each ECCS train draws recirculation suction through the emergency recirculation sump strainers to provide suction flow during the recirculation mode to the respective train's pumps. Also, each primary cooling loop has an accumulator.

The proposed license change does not require any design change to these systems. Thus, system redundancy, independence, and diversity are preserved. The proposed licensing basis change also does not call for any changes to the system operating procedures. These systems have been fully analyzed relative to their contribution to nuclear safety through the Callaway plant-specific PRA. The PRA includes the risk contributions for the full spectrum of LOCA events and meets industry PRA standards for risk-informed applications. The treatment of uncertainties in the risk-informed model ensures results are obtained for realistic assessments. The uncertainties using the risk-informed approach methodology have been examined in the PRA and there are no risk outliers.

Defenses against potential common-cause failures are preserved, and the potential for the introduction of new common-cause failure mechanisms is assessed.

The proposed license change does not change any defenses against common-cause failures. A potential common cause failure would be the recirculation strainer becoming clogged so that there would not be adequate flow to any of the ECCS and CS pumps. The defenses that apply to potential strainer clogging (for example refilling the RWST, use of alternate injection sources, and stopping/starting of pumps) are not changed by the use of the risk-informed methodology since there are no design changes to the equipment or changes to the EOPs.

The potential for new common-cause failure mechanisms has been assessed for the GL 2004-02 issues through decades of plant-specific and industry research. The primary failure mechanisms of concern are recirculation strainer clogging or in-vessel effects. However, the defenses against impediments to cooling delivery or impediments to heat rejection in the core are effective, reasonable, and acceptable operational measures to mitigate or ameliorate adverse strainer performance. Additionally, these defenses do not change due to the proposed licensing basis change to use the RG 1.174 risk-informed approach. Since the risk-informed approach does not involve any design changes to the equipment or changes to the operating procedures beyond those already taken in response to the concerns raised in GL 2004-02, it does not introduce any new common-cause failures or reduce the current plant defenses against common-cause failures.

Independence of barriers is not degraded.

The three barriers to a radioactive release are fuel cladding, RCS piping and components, and the containment building. For the evaluation of a LOCA, the RCS barrier is postulated to be breached. The proposed licensing basis change does not involve any change to the design and analysis requirements for the fuel. Thus, the fuel barrier independence is not degraded. Consequently, the risk-informed GL 2004-02 analysis approach focuses primarily on addressing the integrity of the fuel cladding by assuring the ECCS and CS cooling function is maintained. The Callaway risk-informed evaluation includes both the ECCS and CS cooling function and the containment function.

In the recirculation mode of accident mitigation, the post-LOCA fluid that collects in the containment sump pits is pumped by the CCP and CS pumps that are located in the Auxiliary Building. Thus, the recirculated fluid goes from the containment to the Auxiliary Building and back to the containment. The barrier to release from the Auxiliary Building is the ECCS and CS piping and components in the recirculation flow path. The Auxiliary Building heating, ventilation, and air conditioning (HVAC) system has filters to handle gaseous leakage that would come from any recirculating sump water leakage in the Auxiliary Building. The proposed licensing basis change does not involve any change to the design and operating requirements for this equipment. Thus, there is no change to the containment cooling water recirculation flow path.

The containment is fully analyzed for not only design basis considerations but also from a Level 2 PRA perspective. Detailed analyses for severe accident phenomena, including LOCAs, have been evaluated for impact to containment building integrity; and these events do not challenge the overall capability of containment to remain intact. Also, it should be noted that additional DID capability is available through the use of the CACs. The CACs have enough cooling capability to remove decay heat from the containment through containment atmosphere cooling during the ECCS and CS recirculation phase thereby further reducing containment integrity challenges.

The proposed license change does not involve any design change to these barriers (fuel, piping, building, HVAC filters). Thus, the independence of the barriers is maintained and not degraded.

Defenses against human errors are preserved.

The proposed license change does not involve any design change to the current equipment or operating procedures. Operator actions during the initial accident mitigation stage are focused on monitoring of the automatic mitigation actions and performing manual actions to switchover several pumps from injection mode to recirculation mode. Prior to depletion of the RWST, there is an automatic switchover of the low head RHR pumps, while operator action is required to switchover the intermediate head SI pumps, high head CCPs, and CS pumps. As part of the switchover sequence, operators close the individual pump suction valves associated with the RWST. Also in accordance with EOPs, the switchover from cold leg injection to core flush (combined cold leg and hot leg injection) is a manual action performed by the operator. The use of the methodology for the risk-informed approach does not change any of the EOPs that would be used or impose any additional operator actions or complexity. Thus, the defenses that are already in place with respect to human errors are not impacted by the proposed licensing basis change.

The intent of the plant's design criteria is maintained.

The proposed license change does not involve any change to the design or design requirements of the current plant equipment associated with GL 2004-02. Based on results of the proposed license change showing that the risk-informed approach meets RG 1.174 acceptance criteria, the proposed license change revises the licensing basis for acceptable emergency recirculation sump strainer design and performance in support of ECCS and CS operation in recirculation mode following postulated LOCAs. Therefore, the intent of the plant's design criteria is maintained.

Design and licensing basis descriptions of accidents requiring ECCS and CS operation including analysis methods, assumptions, and results provided in Final Safety Analysis Report (FSAR) Chapters 6 and 15 remain unchanged. The proposed change to the licensing basis continues to meet the intent of the general design criteria (GDC) that apply to functions addressed by GL 2004-02. This conclusion is based on the results of the risk-informed approach that demonstrate that the calculated risk associated with GL 2004-02 concerns for Callaway is very small and in accordance with the Region III acceptance guidelines defined by RG 1.174.

Performance evaluations for accidents requiring ECCS and CS operation described in FSAR Chapters 6 and 15 are based on the Callaway 10 CFR 50, Appendix K large-break LOCA analysis. These evaluations demonstrate that for breaks up to and including the DEGB of a reactor coolant pipe, the ECCS will limit the clad temperature to below the limit specified in 10 CFR 50.46, thus assuring that the core will remain in place and substantially intact with its essential heat transfer geometry preserved. The proposed license change does not involve a change to the ECCS acceptance criteria specified in 10 CFR 50.46. Therefore, the intent of the plant's design criteria is maintained.

2.3 NEI Guidance for Defense-in-Depth Measures in Support of Response to GL 2004-02

For the purposes of GL 2004-02 resolution, the primary regulatory objective is specified in 10 CFR 50.46(b)(5) as long-term cooling. A method for ensuring adequate DID is to maintain the capability for operators to detect and mitigate inadequate flow through recirculation strainers and inadequate flow through the reactor core due to the potential impacts of debris blockage. The following evaluation of the DID measures that support the application for a risk-informed approach to closing GL 2004-02 is based on NEI guidance that includes additional justification for the measures discussed.

2.3.1 Prevention of Inadequate Recirculation Strainer Flow

Callaway has within their EOP framework, specific steps for monitoring for indications of sump strainer blockage and actions to be taken if this condition occurs. These actions are described in the Callaway response to NRC Bulletin 2003-01 and the subsequent responses to the NRC requests for additional information. The actions taken in response to NRC Bulletin 2003-01 are still in effect at Callaway.

In summary, these actions include (1) reducing flow through the strainer by stopping pumps, (2) monitoring for proper pump operation, core exit thermocouples, and reactor water level indication, (3) refilling the RWST for injection flow, (4) using injection flow from alternate sources, and (5) transferring to combined hot leg/cold leg injection flow paths.

Callaway EOPs that implement these actions include:

- E-0, Reactor Trip or Safety Injection EOP
- E-1, Loss of Reactor or Secondary Coolant
- ECA-1.1, Loss of Emergency Coolant
- ECA-1.2, LOCA Outside Containment
- ES-0.1, Reactor Trip Response
- ES-0.2, Natural Circulation Cooldown
- ES-1.1, SI Termination
- ES-1.2, Post-LOCA Cooldown and Depressurization
- ES-1.3, Transfer to Cold Leg Recirculation
- ES-1.4, Transfer to Hot Leg Recirculation
- FR-C.1, Response to Inadequate Core Cooling
- FR-C.2, Response to Degraded Core Cooling
- FR-Z.1, Response to High Containment Pressure
- FR-Z.3, Response to High Containment Radiation Level
- FR-1.2, Response to Low Pressurizer Level
- SAG-3, Severe Accident Control Room Guideline After the TSC is Functional

2.3.2 Detection of Inadequate Strainer Flow

Callaway has operational procedures to monitor the ECCS and CS pump flow, discharge pressure, and amperage. By monitoring these operating parameters, control room personnel could properly diagnose the occurrence of cavitation, which would be an indication of sump clogging or significant deaeration. Control room personnel have been trained to evaluate this type of indication and take appropriate action such as reducing strainer flow rate by securing containment spray pumps.

2.3.3 Mitigation of Inadequate Recirculation Strainer Flow

RWST Refill and Realignment for Injection Flow – The Callaway Emergency Response Plan Implementing Procedures (ERPIPs) provide guidance for refilling the RWST and realigning the ECCS system for injection flow. Refilling the RWST and realigning the ECCS system for injection flow will increase containment water level which will reduce the potential for deaeration and cavitation. Also, terminating recirculation flow temporarily may allow buoyancy forces to eject the non-condensable gases inside the strainer effectively back-flushing and disrupting the debris bed. The disrupted debris bed may potentially fall to the bottom of the sump pit as agglomerated large clumps of debris which would not be expected to re-suspend in the flow and transport back to the strainer pockets.

In response to the NRC Order EA-12-049, “Mitigation Strategies for Beyond-Design-Basis External Event (BDBEE)”, Callaway developed diverse and flexible coping strategies (FLEX) to maintain RCS inventory control, RCS cooling, and containment integrity. Various modifications have been implemented such that non-emergency equipment can be credited during an event.

2.3.4 Prevention of Inadequate Reactor Core Flow

Callaway successfully performed in-vessel analysis per WCAP-17788 methodology for hot and cold leg breaks, which did not result in addition contributions to core damage. DID measures for inadequate reactor core flow are described in the following paragraphs.

2.3.5 Detection of Inadequate Reactor Core Flow

Inadequate core cooling due to debris blocking the core or boric acid precipitation would be primarily indicated by an increase in core exit thermocouple temperature. Reactor vessel water level and containment radiation levels are also monitored to identify inadequate reactor core flow.

2.3.6 Mitigation of Inadequate Reactor Core Flow

FR-C.1 and FR-C.2 provide operator guidance for commencing core flush to restore and maintain RCS subcooling. Also, as discussed in Section 2.3.3, the FLEX RCS

Makeup Pump can be used to inject coolant into the RCS should the emergency recirculation strainer fail.

2.3.7 Implementation of SAMGs and the Plant Engineering Staff Evaluation Manual

SAMGs provide additional guidance and actions for addressing inadequate core flow conditions. Typically, SAMGs will be entered when directed by the EOPs and are used without Technical Support Center (TSC) Engineer involvement. The SAMGs provide guidance for flooding containment above the reactor vessel hot and cold leg nozzles thus covering the break location to provide convective circulation cooling of the reactor vessel. EOPs may direct operators to Engineering for guidance, where TSC engineers consult the Plant Engineering Staff Evaluation Manual to provide Operations with additional guidance during the mitigation of an accident.

2.4 Training Related to the Proposed Change

The proposed change does not result in changes to the symptom–based response procedures and guidelines beyond those already implemented in response to Bulletin 2003-01 and GL 2004-02. Initial training on sump blockage issues was completed, and licensed operator classroom and simulator training on indications of, and responses to, degraded pump flow indications which may be caused by containment emergency sump clogging is provided during initial and requalification training. Training has been conducted for Emergency Response Organization decision makers and evaluators in the TSC on indications of sump blockage and compensatory actions.

2.5 Barriers for Release of Radioactivity

The following evaluation demonstrates that the proposed change maintains sufficient safety margin for the current barriers for release of radioactivity, which are the fuel cladding, the RCS boundary, the containment, and the Emergency Plan (EP) actions. The evaluation concludes that the proposed licensing basis change:

- Does not affect or remove any of these levels of protection.
- Does not result in a significant increase in the existing challenges to the integrity of the barriers.
- Does not significantly change the failure probability of any individual barrier.
- Does not introduce new or additional failure dependencies among barriers that significantly increase the likelihood of failure when compared to the existing conditions.
- Does not change the overall redundancy and diversity features among the barriers that are sufficient to ensure compatibility with the risk acceptance guidelines.

2.5.1 Fuel Cladding

The fuel cladding barrier is maintained by the ECCS following a LOCA. After the initial phase of the accident mitigation, long term cooling is maintained post-LOCA by the ECCS and shutdown cooling system. The proposed licensing basis change for the change in methodology to use a RG 1.174 risk-informed approach for the effects of debris does not make any change to the previous analyses and testing programs that demonstrate the acceptability of the ECCS for the initial phase of providing core cooling. The proposed licensing basis change shows that long term cooling is met for the additional accident mitigation and recovery phase for the LOCAs in the deterministic scope of the GL 2004-02 evaluation. The evaluation of DID and safety margin provides confidence that adequate mitigation will be provided for the risk-informed scope of the GL 2004-02 evaluation. The proposed license change does not involve any change to the design or design requirements of the current plant equipment associated with GL 2004-02. There is no change to the design and analysis requirements for the fuel. Therefore, the fuel cladding barrier is expected to be maintained by the ECCS following a risk significant LOCA.

2.5.1.1 Emergency Core Cooling

Callaway has a system to provide abundant emergency core cooling. The system safety function is to transfer heat from the reactor core following any loss of reactor coolant at a rate such that: (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and; (2) clad metal-water reaction is limited to negligible amounts. Suitable redundancy in components and features, and suitable interconnections, leak detection, isolation, and containment capabilities are provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure.

2.5.1.2 Long Term Cooling

To comply with 10 CFR 50.46(b)(5), “Long-term cooling,” the Callaway RG 1.174 risk-informed approach for post-LOCA sump performance shows that after the successful initial operation of the ECCS, the core temperature is maintained at an acceptable low value and decay heat is removed for the extended period of time required by the long-lived radioactivity remaining in the core.

2.5.2 Reactor Coolant System Pressure Boundary

Integrity of the RCS pressure boundary is postulated to be broken for the GL 2004-02 sump performance evaluation that is concerned with post-LOCA debris effects. However, the proposed change does not make any change to the previous analyses and testing programs that demonstrate the integrity of the RCS. Since the proposed licensing basis change does not impact any design or programmatic requirements for the reactor coolant pressure boundary, the likelihood of a LOCA is not affected.

2.5.2.1 In-Service Inspection Program

The ISI program performs an important role in the prevention of pipe breaks. The integrity of the welds in ASME Class 1 piping and components are maintained at a high level of reliability through the ASME Section XI inspection program. The Callaway ISI program procedure ensures that the following requirements of 10 CFR 50.55a and ASME/BPVC Section XI, 2007 Edition through 2008 Addenda are satisfied:

- Verification of the structural integrity of ASME Class 1, 2, and 3 components are within the limits specified in the In-Service Inspection Program, and
- Verification of the structural integrity of the main steam and main feedwater piping is within the limits specified in the augmented In-Service Inspection Program.

2.5.2.2 Reactor Coolant System Weld Mitigation

All large bore reactor vessel welds susceptible to pressurized water stress corrosion cracking (PWSCC) have been mitigated by water jet peening in 2017.

2.5.2.3 RCS Leakage Detection

The leak detection program at Callaway is capable of early identification of RCS leakage in accordance with RG 1.45 to provide time for appropriate operator action to identify and address RCS leakage. The effectiveness of this program is not reduced by the proposed licensing basis change to the risk–informed approach for GL 2004-02.

2.5.3 Containment Integrity

The evaluation of sump performance using a risk-informed approach is not a component of the analyses that demonstrates containment integrity. Previous analyses show that the containment structure can withstand the peak pressures calculated without loss of integrity. The containment remains a low leakage barrier against the release of fission products for the duration of postulated LOCAs.

2.5.3.1 Containment Design Basis

The principal design basis for the containment is that it be capable of withstanding the internal pressure resulting from a LOCA with no loss of integrity. In this event, the total energy contained in the water of the RCS is assumed to be released into the containment atmosphere through a break in the reactor coolant piping. Subsequent pressure behavior is determined by the building volume, engineered safety features, and the combined influence of energy sources and heat sinks.

2.5.3.2 Containment Heat Removal

The proposed license change does not involve changes to the design or design requirements of the current plant equipment associated with GL 2004-02. Thus, there is no change to any of the containment heat removal components needed to maintain containment integrity. Therefore, the proposed change does not significantly impact the structural capability and integrity of the containment as an effective fission product barrier post-LOCA. The Callaway large, dry containment with safety-grade CACs is likely to survive a significant core damage event, even with a loss of the containment emergency recirculation sump.

CACs are designed to operate independently in the post-LOCA environment and are not directly affected by the loss of the recirculation sump or containment spray. This additional and independent capability to reject decay heat from containment ensures that the containment would not fail because of overpressure or overheating. Although core melt could be postulated, containment integrity would be maintained by operation of the CACs and the containment would continue to be maintained as an effective fission product barrier.

Energy released to the containment atmosphere from the postulated accidents is removed by the CS and CACs. Callaway has four cooling units located entirely within the containment. Safety-related ESW is circulated through the air cooling coils during an event. The CACs are designed to remove heat from the containment during both normal operation and accident conditions. (During normal operation non-safety-related service water is circulated through the CACs.)

Upon receipt of a safety injection signal (SIS), any idle cooling unit is automatically started and, simultaneously, any running fan is switched from the normally operating high speed setting to low speed operation. The CACs are supplied cooling water from the safety-related ESW.

The CACs remove thermal energy from inside the containment to reduce the containment atmosphere pressure and temperature following loss-of-offsite power (LOOP) or a design basis accident (DBA). The containment response analysis evaluated many single failure scenarios ranging from single component failure to complete train failure and allowable peak pressure and temperature of the containment was not reached following a DBA.

Other industry studies have indicated the ability of the containment systems to survive challenges of 2.5 to 3 times the design levels. The Zion Probabilistic Safety Study showed that the containment ultimate capacity was 2.55 to 2.86 times the design capacity.

2.5.3.3 Containment Testing

TS Surveillance Requirement 3.6.1.1 requires a Containment Leakage Rate Testing Program to be established to implement leakage rate testing of the containment as required by 10 CFR 50.54(o) and 10 CFR 50, Appendix J, Option B, as modified by approved exemptions. This program is in accordance with the guidelines contained in RG 1.163.

The proposed change does not impact the requirements for structural integrity and leak-tightness of the containment and does not involve any changes to the containment leakage testing requirements for demonstrating the effectiveness of the containment as a low leakage barrier.

2.5.4 Emergency Plan Actions

The proposed change to the licensing basis to use the methodology of a risk-informed approach does not involve any changes to the Emergency Plan. There is no change to the strategies for prevention of core damage, for prevention of containment failure, or for consequence mitigation. The use of the risk-informed approach does not impose any additional operator actions or complexity. Implementation of the proposed change would not result in any changes to the response requirements for emergency response personnel during an accident. The DID approach includes the ability to detect, prevent, and mitigate post–LOCA strainer debris blockage and in–vessel debris blockage.

3 Safety Margin

There are numerous conservatisms used throughout the Callaway risk-informed GL 2004-02 evaluation. The safety margin evaluation identifies margins and conservatisms in the design, analysis, construction, and operation of the plant to show that the proposed methodology change by this licensing submittal will maintain sufficient safety margins. Per the guidance stated in RG 1.174, the evaluation of the proposed change shows that sufficient safety margins exist to ensure:

- Codes and standards or their alternatives approved for use by the NRC are met.
- Safety analysis acceptance criteria in the FSAR and supporting analyses are met or proposed revisions provide sufficient margin to account for analysis and data uncertainty.

3.1 Break Selection

The RoverD approach implemented CASA Grande to automate the zone of influence (ZOI) debris generation and analyze each weld location for DEGB, spherical ZOI destruction, as well as partial-break, hemispherical ZOI destruction. Fiber debris generation at each location and for each break size is determined. Since all weld locations in ASME Class 1 piping are analyzed for various break sizes, a break selection criterion is not needed.

3.2 Debris Generation

Debris generation analysis was performed in accordance with approved methods documented in NEI 04-07 that include multiple levels of conservatism:

- Smaller piping ruptures, while still unlikely, provide a better measure of expected behavior.
- The wide recognition that a large RCS pipe is more likely to leak and be detected by the plant's leakage monitoring systems long before cracks grow to unstable sizes is referred to as leak before break and is an accepted part of regulatory compliance with GDC 4.
- Full destruction of materials is assumed within a conservatively determined spherical ZOI based upon a conservative extrapolation of limited test data performed under non-prototypic conditions, with limiting configurations. Sparse data on insulation destruction testing has forced the use of bounding results. All insulation is presumed to have a worst case seam orientation relative to the break. The ZOI for insulation materials is expected to be significantly smaller than that predicted by the NRC guidance due to real factors such as greater structural integrity than tested materials, non-limiting seam orientations, etc.
- The debris generation analysis does not take credit for shielding within the ZOI by equipment (e.g. steam generators, reactor coolant pumps) and large piping.
- Instantaneous failure of 100% of the unqualified coatings inside containment as particulates is a very conservative assumption.
- Latent debris evaluations were completed in accordance with the approved guidance documented in NEI 04-07. The results of the latent debris calculation conservatively determined the debris loading to be less than 100 lbm in each containment building.

3.3 Debris Transport

Debris transport analysis was performed in accordance with approved methods documented in NEI 04-07, that include multiple levels of conservatism:

- All fine debris is assumed to wash down to the sump pool elevation with no holdup on structures. Although fine debris would be easily carried by draining spray flow, a quantity of fine debris would likely be retained on walls and structures above the containment pool due to incomplete spray coverage and hold up on structures. Even in areas that are directly impacted by sprays, some amount of fine debris would agglomerate together and likely be held up.
- Most fine debris is assumed to transport to the surface of the strainer. Debris present or generated at the beginning of the event will generally be pushed by break and spray flows into quiescent regions and will reside as debris piles. At the start of recirculation, it would take substantially higher flow rate than what would actually occur to cause movement of these piles of debris. Even if these

piles of debris were to move, there are numerous obstacles (supports, equipment, curbs, etc.) that would prevent debris from reaching the strainers.

- For each debris type and size, debris transport fractions were determined at four break locations. The largest transport fraction for each debris type and size was implemented for RoverD analysis.
- Debris barriers, which are similar to debris interceptors, are installed in all the openings through the secondary shield wall nearest to the emergency recirculation sumps. These openings provide the most direct path from inside the secondary shield wall to the strainers. However, debris barriers were not credited for debris retention.

3.4 Chemical Effects Predictions

Chemical effects analysis was performed in accordance with approved guidance documented in WCAP-16530-NP-A that includes multiple levels of conservatism:

- WCAP-16530 relies largely upon short-term release rates (hours) for the determination of long-term releases (30 days). Long-term release rates of constituent materials are expected to be significantly lower than that predicted by design basis models due to saturation, surface passivation, inhibition effects due to other ions, and formation of surface films.
- One hundred percent of chemical species of interest are assumed to precipitate. When solubility limits are taken into account, the predicted precipitation is reduced by a significant factor. In addition, precipitates will form during periods when net positive suction head margins are greater.
- The WCAP-16530 models result in chemical precipitate formation that is completely transported to the sump screen. A portion of precipitates generated will not reach the containment sump strainers because precipitates will deposit on other surfaces in containment.
- The pH profile had a steady state pH equal to the highest deterministic pH bound.
- The pilot plant and Callaway have similar conditions (pH, temperature, material inventories, etc.). Therefore, trends from the chemical effects tests conducted by the pilot plant are applicable to Callaway. Results and conclusions of chemical effects testing conducted by the pilot plant are below.
    - Integrated corrosion tests with bounding conditions for large breaks show relatively little precipitate formation.
    - Vertical loop head loss tests with dissolved aluminum show that precipitate formation would not occur prior to significant pool cooling (days into the event).

3.5 Strainer Head Loss Tests

Strainer head loss tests were performed in 2016 at Alden Research Laboratories in accordance with the NRC guidance and included multiple levels of conservatism:

- During strainer head loss tests, fiber fines were conservatively implemented as the surrogate for small and large pieces of fiber. This is conservative because small and large pieces of fiber typically reduce debris bed head loss. Should large quantities of debris be generated and transported to the strainer, it would be a mixture of fiber fines, small pieces, and large pieces.
- During head loss tests, all fiber and particulate debris was collected on the strainer prior to addition of chemical precipitates. The chemical precipitate coating on the debris bed observed in head loss testing is not prototypical. In reality it would be less uniform than that achieved during testing since some of the precipitates would be expected to form in the debris bed, producing a less uniform deposit. A less uniform deposition of precipitates would yield a lower debris bed head loss.
- The head loss tests did not credit near-field settling, which was credited by the pilot with the implementation of a test flume. Callaway head loss tests were conducted in a test tank that was designed to promote complete and uniform transport by inducing non-prototypical turbulence and neglecting the six-inch curb surrounding the strainers installed in Callaway containment.
- Metallic insulation debris and paint chips were excluded from the tested debris loads in order to conservatively bound head loss. This debris is predicted to transport to the strainer and would disrupt the formation of a uniform fiber/particulate debris bed. This results in lower strainer head loss. Also, particulate was implemented as a surrogate for the paint chips.
- Strainer head loss tests were conducted at an approach velocity approximately 15% larger than the expected approach velocity. Note, the expected approach velocity accounted for miscellaneous debris. This results in larger head losses and is conservative.

3.6 Strainer Performance

Strainer performance considerations include net positive suction head (NPSH), air release, potential for flashing, vortex formation, and structural qualification. These analyses included multiple levels of conservatism:

- The maximum strainer head loss is applied at the beginning of the event, which inherently assumes all debris (conventional debris, eroded debris, and chemical precipitates) is on the strainer at the very beginning of recirculation. In reality, debris accumulates on the strainer over time when margins are greater.
- The minimum pool height is calculated based on several conservative inputs with conditions that Callaway has never realized during its operational history. For example, the calculation assumes the refueling water storage tank water level is at the technical specification minimum, while Callaway’s operational history shows more water is always in the refueling water storage tank. These assumptions reduce the water level in containment, as well as the margin.

- Strainer head losses determined by tests at a temperature of 120 °F were conservatively applied at increased temperatures without any scaling. This results in the application of larger strainer head losses, which reduces margin.
- Strainer head losses determined by tests at an approach velocity approximately 15% greater than the expectation were conservatively applied without scaling. This results in the application of larger strainer head losses, which reduces margin.
- For the structural analysis, loads such as change in pressure due to post-LOCA debris and inertial forces due to a safe shutdown earthquake are concurrently analyzed. This increases the forces on the strainer and over estimates stresses.

3.7 RoverD and Risk

The RoverD analysis adheres to the pilot plants methodology with multiple levels of conservatism:

- For the pilot plant, the RoverD risk metric is fine LDFG but Callaway implemented a risk metric that included all LDFG (fine, small, large, eroded LDFG, latent LDFG, and fiber safety margin) that is transported to the strainer. The additional conservatism that Callaway applied causes more breaks to be assumed to failure.
- Callaway performed RoverD analysis assuming a single operable train. This results in a conservative quantification of change in core damage frequency.
- A fiber safety margin of 50 lbm is applied to all postulated breaks. This 50 lbm of fiber is in addition to ZOI-generated and latent fiber sources. This 50 lbm margin provides additional assurance that the quantified change in core damage risk is conservative.