Illustrative Examples
For use in Preparation of Supplemental Responses
To Generic Letter 2004-02

DRAFT 10/2/2007

Table 3a Illustrative Example – Break Selection

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

[Plant] evaluated a number of break locations and piping systems, and considered breaks that rely on recirculation to mitigate the event. The following break location criteria were considered:
Break Criterion No. 1 - Breaks in the RCS with the largest potential for debris;
Break Criterion No. 2 - Large breaks with two or more different types of debris;
Break Criterion No. 3 - Breaks with the most direct path to the sump;
Break Criterion No. 4 - Large breaks with the largest potential particulate debris to insulation ratio by weight; and
Break Criterion No. 5 - Breaks that generate a “thin-bed” - high particulate with 1/8" fiber bed.

This spectrum of breaks is consistent with that recommended in the SE and is also consistent with regulatory position 1.3.2.3 of Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," Revision 3 [4].

[Plant] considered breaks in the primary coolant system piping having the potential for reliance on ECCS sump recirculation. The review determined that a primary coolant system piping large break loss of coolant accident (LBLOCA) and certain primary coolant system piping small break LOCAs (SBLOCAs) would require ECCS sump recirculation. [Plant]considered other high energy line breaks (e.g., secondary side breaks) and determined that sump operation was not required.

For small breaks, only piping that is 2" in diameter and larger was considered. This is consistent with the Section 3.3.4.1 of the SE, which states that breaks less than 2 inches in diameter need not be considered. Section 3.3.5 of the SE describes a systematic licensee approach to the break selection process which includes beginning the evaluation at an initial location along a pipe and stepping along in equal increments (5 foot increments per the SE) considering breaks at each sequential location. However, due to the size of the ZOI applied in the analyses, and the consequent volume of debris generated, it was not necessary to evaluate 5-ft increments.

The evaluation identified break locations that provided limiting conditions for each of the 5 break selection criteria above. For SE break selection criterion No. 1, three possible breaks locations were identified: both loops of the RCS hot leg inside steam generator compartments inside the bioshield; and a break at the reactor vessel nozzles. The results of the evaluation of insulation debris generation for Break Criterion No. 1 determined that all three breaks are limiting based on either the type or amount of debris generated.

It was determined that the debris generated by the three limiting cases for Break Criterion No. 1 bounded the debris generated for Break Criterion No. 2 “large breaks with two or more different types of debris.” The debris combinations generated by the breaks of Break Criterion No. 1 are reflective metal insulation (RMI) and mineral wool, and RMI and MicrothermTM. The evaluation concluded that these three breaks generate the largest amount of debris, and also the most limiting combinations of debris.

For Break Criterion No. 3, "breaks with the most direct path to the sump," the evaluation concluded that the most limiting case is a break at the 16-in shutdown cooling line. P&IDs (piping and instrument diagrams), as well as piping arrangement, plan and physical arrangement drawings were used to determine possible break locations.

For break selection criterion No. 4, "large breaks with the largest potential particulate debris to insulation ratio by weight," the evaluation concluded that the most limiting case is a break at a reactor vessel nozzle within the reactor cavity, which is bounded by Break Criterion No. 1. Of the three different types of insulation identified within the containment, MicrothermTM is predominately particulate insulation material. This type of insulation is on the reactor vessel.

For break selection criterion No. 5, "breaks that generate a thin-bed," the evaluation identified two possible breaks locations: break at the hot leg and a break at the reactor vessel nozzle, which are bounded by Break Criterion No. 1

To develop a head-loss margin analytical conservatism for possible future use, [plant] evaluated the potential reduction in debris source term following replacement of the mineral wool on the steam generators with RMI. The insulation replacements will be performed in the Unit 2 October, 2009 outage and in the Unit 3 October, 2010 outage. The insulation replacement does not change the break selection results.

In summary, [plant] determined that a postulated LBLOCA within Loop 1 and 2 at the steam generator hot legs generates the largest quantities of mineral wool and RMI debris. A break near the reactor vessel nozzle generates a large amount of RMI and MicrothermTM debris. A break at the 16-in shutdown cooling line is considered in the proximity of the sump, and generates mineral wool and RMI debris which will likely transport to the containment emergency sump. It was concluded that these reactor coolant system breaks generate the largest amount of debris, and also the worst combination of debris with the possibility of being transported to the containment emergency sump strainer.

All phases of the plant-specific accident scenarios were evaluated to develop debris generation values for the breaks listed in the previous summary paragraph. These accident scenario cases are:

1. Case 1: RCS hot leg break inside SG compartment Loop 1 (limiting break for SE break selection criteria 1, 2 and 5);
2. Case 2: RCS hot leg break inside SG compartment Loop 2 (limiting break for SE break selection criteria 1, 2 and 5);
3. Case 3: Nozzle break in reactor cavity (limiting break for SE break selection criteria 1, 2, 4 and 5)
4. Case 4: Shutdown cooling line break outside SG compartments (limiting break for SE break selection criterion 3); and
5. Case 5: Hot leg break after steam generator replacement.

Table 3b Illustrative Example – Debris Generation/ZOI (excluding coatings)

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

[Plant] applied the ZOI refinement discussed in Section 4.2.2.1.1 of the SE, which allows the use of debris-specific spherical ZOIs. Using this approach, the amount of debris generated within each ZOI is calculated and the individual contributions from each debris type are summed to arrive at a total debris source term.

The sources of debris at [Plant] include insulation debris, coatings debris, and latent debris. The evaluation concluded that there are two types of insulation inside the containment that could potentially form debris following a LOCA. These insulations are: 1) Transco reflective metallic insulation (RMI) and 2) mineral wool encased inside a Transco stainless steel (SS) cassette.

Damage Pressures and Corresponding Volume-Equivalent Spherical ZOI Radii

Insulation Types	**Destruction Pressure (psig)**	**ZOI Radius/Break Diameter**
Transco RMI	114	2.0
Jacketed Mineral Wool		4.0

For the Transco RMI and unjacketed NUKON insulation at [plant], the evaluation assumed a ZOI size in accordance with the guidance in the SE. For the mineral wool at [plant], the SE Table 3-2 does not provide specific guidance. The mineral wool insulation that will remain in service at [plant] is contained in an engineered system comprised of cassettes that are constructed exactly the same as the Transco RMI used at [plant]. These cassettes are constructed of 24 gauge steel with the casing end seams seal welded. Based on the robust nature of this encapsulation/jacketing system, the ZOI for the mineral wool would be closer to Transco RMI than unjacketed NUKON. To ensure conservatism, the evaluation doubled the ZOI from the Transco RMI (2D out to 4D).

Insulation Debris Quantities

Insulation	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Transco RMI	7096 ft2	7549 ft2	7530 ft2	815 ft2	7096 ft2
Mineral Wool	81 ft3	81 ft3	0	0	12 ft3

Table 3c Illustrative Example – Debris Characteristics

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

The debris sources at [Plant] include insulation, coating, and latent debris. The insulation debris includes both fiber (Nukon, Kaowool, and generic fiberglass) and Transco stainless steel reflective metallic insulation (RMI). The characteristics of the insulation debris material are discussed in this section as the characteristics of the other debris types (e.g. coatings and latent) are included elsewhere.

3c.1 Size Distribution

3c.1.1 Nukon

For [Plant], only Nukon within a break ZOI of 8D becomes debris per [Reference]. Within this ZOI, all Nukon debris is considered fines and small debris based on the expected jet pressures within the ZOI and Figure II-2 of Appendix II to the SE which shows the fraction of small fines as a function of jet pressure. Note that the air jet pressures reported in Figure II-2 are adjusted prior to use to account for the potentially enhanced debris generated due to a PWR jet in accordance with the Staff Evaluation of GR Section 3.4.2.2 in the SE. Consistent with the DDTS results discussed in Appendix II to the SE, 25% of the fines and small debris is considered fines and 75% is considered small pieces.

Fines are the constituent part of the insulation and are considered 100% transportable. Small pieces are pieces less than 4 inches square per [Reference].

3.c.1.2 Kaowool

The debris size distribution for Kaowool debris is assumed to be the same as for Nukon debris. Both Kaowool and Nukon are fibrous material with similar fiber densities per Table 3-2 of the GR. Also, the bulk density of the Kaowool at [Plant] is much greater than that of Nukon (see below). Therefore, it is expected that Kaowool will actually form less small debris than Nukon when subjected to the same jet pressure. Therefore, it is conservative to assume that both types of insulation will have similar destruction pressures and hence, similar debris size distributions.

3.c.1.3 Generic Fiberglass

Consistent with §3.4.3.3.1 of the GR and Staff Evaluation of GR §3.4.3.3 in the SE, generic fiberglass is modeled as 100% fines since applicable experimental data is not available for this debris type. Fines are the constituent part of the insulation and are considered 100% transportable.

3.c.1.4 Transco RMI

Transco RMI is modeled as 100% small pieces which are less than 4 inches per [Reference]. This is more conservative than the guidance in §3.4.3.3.3 of the GR and Table 3-3 of the SE.

3c.2 Density of Debris

The bulk density of Nukon is 2.4 $\mathrm{lbm/ft^3}$ and the material density of the individual fibers is 159 $\mathrm{lbm/ft^3}$ per Table 3-2 of the GR. Validation that these properties are representative of those for Nukon installed at [Plant] has been performed and is documented in [Reference].

The bulk density of Kaowool ranges from 3 to 12 $\mathrm{lbm/ft^3}$ and the material density of the individual fibers is 160 to 161 $\mathrm{lbm/ft^3}$ per Table 3-2 of the GR. Per [Reference], the Kaowool installed at [Plant] has a bulk density of 8 $\mathrm{lbm/ft^3}$ and a material density of 160 $\mathrm{lbm/ft^3}$.

Per [Reference], the bulk density and material density of generic fiberglass at [Plant] are 6 $\mathrm{lbm/ft^3}$ and 161 $\mathrm{lbm/ft^3}$, respectively.

The Transco RMI foils are made of flat 2 mil thick stainless steel which has a density of 490 $\mathrm{lbm/ft^3}$ per [Reference].

The above densities are used to ensure that the proper materials are used in the bypass and head loss strainer tests.

3c.3 Specific Surface Areas for Debris

Note: the specific surface area (S_v) was only used for preliminary analytically determined head loss values across a debris laden sump screen using the correlation given in NUREG/CR-6224. Since the head loss across the installed sump screen is determined via testing, these values are not used in the design basis for [Plant]. Therefore, these values are not provided as part of this write-up.

Table 3d Illustrative Example – Latent Debris

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

Latent debris has been evaluated via containment condition assessments. Containment walk downs were completed for [plant] Unit 1 during the [Spring 2004 1RF010] outage. Containment walk downs for [plant] Unit 2 were completed during the [Spring 2005, 2RF08] outage. The walk downs were performed using guidance provided in NEI 02-01, "Condition Assessment Guidelines, Debris Sources inside Containment," Revision 1 [Ref. X]. The quantity and composition of the latent debris was evaluated by extensive sampling for latent debris (dust and lint) considering guidance in NEI 04-07 Volume 2 (i.e., the NRC SER). Supplementary walkdowns to assess containment conditions were performed in [September 2004, May 2005, June 2005, October 2005, December 2006, and July 2007.]

Samples were taken to determine the latent debris mass distribution per unit area, referred to as latent debris density (e.g. lbm/1000 ft2) of representative surfaces throughout containment including vertical surfaces such as the liner and walls. These debris densities were then applied to all of the surface areas inside containment to calculate the total amount of latent debris inside containment.

The latent debris density was estimated by weighing sample bags before and after sampling, dividing the net weight increase by the sampled surface area, adjusting the result based on an estimated sample efficiency, and converting the result to a density (e.g. lbm/1000 ft2)

[22] samples were taken for Unit 1 and [73] samples were taken for Unit 2. The visual assessments and walkdowns supported that there were no significant differences between the units that would affect the quantity or types of latent debris. Therefore, the [95] samples taken are representative of both units.

Although the [plant] insulation is predominantly reflective metallic insulation (RMI), the statistical sample mass collections (i.e., three samples from each category of surface) was not used. The loadings of latent debris have been observed to be both light and uniform in both [plant] Unit 1 and Unit 2. Many areas and surfaces cannot be reached for sampling without scaffolding or adding special provisions for fall protection devices. [Plant] used an alternative approach to minimize personnel risk. Representative samples were taken from accessible surfaces. Visual observations of these sample locations were compared to visual observations of other surfaces and conservative estimates of bounding debris loadings were made. The data from Unit 1 and the data from Unit 2 were used to substantiate a common latent debris source term for both units. This exception to NEI 04-07 (GR and SER) for containment condition assessments was previously described in the September 1, 2005 response to the Generic Letter 04-02.

The results of the latent debris calculation conservatively determined the debris loading to be less than 91 lbm in each containment. Therefore, it was elected to use a conservative bounding value of 200 lbm for the latent debris source term in containment.

Visual examination of the debris showed very low fiber content. In lieu of analysis of samples, conservative values for debris composition properties were assumed as recommended by NEI 04-07 Volume 2 (the SER). This results in a very conservative estimate of fiber content. The particulate / fiber mix of the latent debris will be assumed to be 15% fiber. The latent fiber debris is assumed to have a mean density of 94 lbm/ft3 (1.5 g/cm3) and the latent particulate debris a nominal density of 169 lbm/ft3 (2.7 g/cm3). The latent particulate size is assumed to have a specific surface area of 106,000 ft-1. The latent debris fiber bulk density is assumed to be the same as that of LDFG which is 2.4 lb/ft3. The characteristic size of the latent fiberglass is also assumed to be the same as LDFG or approximately 7 microns.

Fiber and particulate debris was observed in most areas of containment, but in varying quantities. Latent debris was primarily found to be particulate such as dirt and dust.
Paint chips were found in some areas as were pieces of gasket material and latex gloves. Several broken ty-wraps were found. In a few instances, some larger latent debris (tools, pens, gloves, etc.) was found in areas that are not regularly accessible.

The containment condition assessments also included the identification of labels and tags. Qualified tags attached with stainless steel wires were found for much of the equipment. There were non-qualified tags found inside containment, as well. There was also approximately 5 ft2 of tape inside containment, based on a conservatively estimated 100 pieces observed.

A sacrificial area of [200] square feet of strainer surface per strainer was designated as a penalty for miscellaneous latent debris including labels and tags. [Plant] has identified tags and labels which are qualified and which have been shown to not transport to the emergency sump strainers (acceptable labels). Miscellaneous latent debris which has not been shown to be acceptable by testing of analysis will be removed to the extent practical. See Section P below.

Miscellaneous latent debris is also discussed in more detail in the debris transport section below.

Table 3e Illustrative Example – Debris Transport

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

[Plant Name] applied the approach described in Section 3.6 of NEI 04-07 and the modifications identified in Section 3.6 of the NRC SE on NEI 04-07 to evaluate debris transport to the reactor containment building sump for a postulated high energy line break. Debris transport is the estimation of the fraction of debris that is transported from debris sources (break location) to the sump screens. The four major debris transport modes are:

- *Blowdown transport* – the vertical and horizontal transport of debris to all areas of containment by the break jet.

  Include a brief summary description of the distribution of flow from the postulated high energy pipe break about containment; ice condenser plants should note that the flow path from lower containment to upper containment is through the ice condenser.

  Provide a summary description of how the size distribution of debris was evaluated for the blowdown phase of postulated high energy line break. Also provide a summary description of how the split of debris about containment was evaluated for the blowdown phase of a postulated high energy line break. For example, state if a Computer Aided Drawing (CAD) model of the reactor containment building was used. Provide technical basis for how both the size distributions and transport fractions into upper and lower containment were evaluated. Summarize both the size distributions and transport fractions either in a table or a logic tree for each debris type. Table 1 is an example of size distributions evaluated for a large break LOCA. Table 2 is an example of transport fractions into upper containment that were evaluated for a large break LOCA.

- *Washdown transport* – the vertical (downward) transport of debris by the containment spray and break flows.

  Include a brief summary description of the washdown process for the containment. If an ice condenser plant credited the capture of debris in the ice condenser, state that the debris captured in the ice condenser is not subject to washdown due to containment spray. However, include a description of how the water from the ice melt contributed to a washdown-like effect on debris transported into the ice condenser.

  Provide a summary description of the transport fractions evaluated for the washdown process, along with a technical basis for those transport fractions. Summarize the transport fractions in a table or a logic tree for each debris type. Table 2 may be used as example for presenting the washdown transport fractions.

- *Pool fill-up transport* – the transport of debris by break and containment spray flows from the refueling water storage tank (RWST) to regions that may be active or inactive during recirculation.

  Include a brief summary description of the transport of debris due to emptying the RWST into the reactor containment building. Identify transport of debris into inactive compartments.

  Provide a summary description of the transport fractions evaluated for the pool fill-up process, along with a technical basis for those transport fractions, including the transport fractions of debris to inactive areas of the containment. Summarize the transport fractions in a table or a logic tree for each debris type.

  Table 2 may be used as example for presenting the pool fill-up transport fractions.

- *Recirculation transport* – the horizontal transport of debris from the active portions of the recirculation pool to the sump screens by the flow through the emergency core cooling system (ECCS).

  Include a brief summary description of the transport of debris in the pool due to recirculation flow. Include a brief description of the initial debris distribution within the pool and the technical basis for that distribution. Included in the description should be latent debris, unqualified coatings, fines, and small and large pieces of debris. If the plant has fiberglass insulation and the erosion factor used for fiberglass is different from the 90% value identified in the NRC SE on NEI 04-07, include the technical basis for using a different value (i.e., test data).

  Table 2 may be used as example for presenting the recirculation transport fractions.

Table 1: Debris Quantities and Size Distribution for LB LOCA at [LOCATION]			
Debris Type	**Debris Size**	**Debris Quantity**	**Debris Size Distribution**
NUKON™	Individual Fibers	170 ft^3	15%
	Small Pieces (<6″)	600 ft^3	50%
	Large Pieces (>6″)	200 ft^3	15%
	Intact Blankets	200 ft^3	20%
Thermo-Lag™	10-micron particulate	30 lb_m	100%
Coatings Inside ZOI	10-micron particulate	500 lb_m	100%
Coatings Outside ZOI	10-micron particulate	1,500 lb_m	100%
Latent Particulate	20-micron particulate	200 lb_m	100%
Latent Fiber	Individual Fibers	0.5 ft^3	100%
Miscellaneous Debris	Variable	450 ft^3	100%

Table 2: Blowdown Transport Fractions of Debris Into Upper Containment				
Debris Type	**Fines**	**Small Pieces**	**Unjacketed Large Pieces**	**Jacketed Large Pieces**
Stainless Steel RMI	N/A	67%	10%	N/A
NUKON™	80%	64%	10%	10%
Thermo-Lag™	80%	N/A	N/A	N/A
Coatings Inside ZOI	80%	N/A	N/A	N/A
Coatings Outside ZOI	0%	N/A	N/A	N/A
Latent Particulate	0%	N/A	N/A	N/A
Latent Fiber	0%	N/A	N/A	N/A

Note: Table 2 may be used as an example to present debris transport fractions for washdown, pool fill-up and recirculation, as appropriate.

3e.2 Assumptions Used that Deviate from Approved Guidance

No assumptions were made in the analysis for [Plant Name] that deviate from the guidance given by NEI 04-07 as modified by the NRC SE on NEI 04-07.

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Several assumptions were used in the analysis for [Plant Name] that vary from those given in the guidance of NEI 04-07, as modified by the NRC SE. The [examples of] assumptions and the technical basis for them are:

1. It was assumed that the break locations modeled for the LBLOCA and SBLOCA scenarios in the vicinity of Loop C also apply to breaks in other locations inside the bioshield wall. Since all of the debris was conservatively assumed to wash outside the bioshield wall, the actual location of the modeled break flow does not significantly affect debris transport.

2. It was assumed that the reactor containment building will be modified with barriers of some kind that will block the transport of small and large piece debris through the Loop A and Loop D passageways and floor drain trenches. These are planned modifications to prevent debris from transporting directly to the sump screens following a LOCA event. It is noted that the installation of these modifications must be made before the calculation represents the as-configured design of [Plant Name].

3. With the exception of latent debris washed to the sumps and inactive cavities during pool fill-up, it was conservatively assumed that all latent debris is in lower containment, and would be uniformly distributed in the containment pool at the beginning of recirculation. This is a conservative assumption since no credit is taken for debris remaining on structures and equipment above the pool water level.

4. It was assumed that the settling velocity of fine debris (insulation, dirt, dust, and particulate matter) is governed by Stokes' Law. This is a reasonable assumption as the particulate debris is sufficiently small in size that it may be approximated as being generally spherical, and would settle slowly within the applicability of Stokes' Law.

3e.3 Use of Computational Fluid Dynamics Code

[Plant Name] did not use a Computational Fluid Dynamics code to support the evaluation of debris transport fractions during recirculation.

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[Plant Name] applied the debris transport refinement discussed in Section 4.2.4.2 of NEI 04-07, as modified in Section 4.2.4 of the NRC SE on NEI 04-07, which allows the use of Computational Fluid Dynamics (CFD) software. Using this approach, the transport of debris to the reactor containment building sump associated for each postulated high energy pipe break and for each type of debris generated was evaluated.

The [CFD Code Name] was used to perform the flow field calculations for [Plant Name].

Briefly describe the CFD model and show a mesh pattern.

Present, in summary form, the CFD model inputs

Summarize the calculational results, including velocities and transport fractions for each type of debris. Consider showing plots of velocity plots with descriptive text explaining them. If Turbulent Kinetic Energy (TKE) is used to evaluate debris transport, include TKE plots with descriptive text explaining the plots.

3e.4 Debris Interceptors

[Plant Name] did not credit debris interceptors in the evaluation of debris transport to the reactor containment building sump.

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[Plant Name] did not credit debris interceptors in the evaluation of debris transport to the reactor containment building sump. However, large obstacles in the flow path were credited for holding up large debris, such as intact fibrous blankets or large pieces of reflective metallic insulation (RMI). The basis for this is credit is the flume test data documented in NUREG/CR-6808 that demonstrates debris buildup behind curbs in front of the sump screen. This behavior would also be expected at obstacles upstream of the sump screen. [If available, plant-specific flume testing may also be used to demonstrate debris collection by obstacles upstream of the sump.]

- or -

[Plant] did credit debris interceptors in the evaluation of debris transport to the reactor containment building sump. This credit was based on testing of debris interceptors with debris loading specific to [Plant Name].

3e.5 Settling of Debris Fines

[Plant Name] did not credit the settling of debris fines in the debris transport calculation.

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[Plant Name] did credit the settling of debris fines in the debris transport calculation. The amount of settling credited is based on flume testing performed for the replacement sump screen. The technical basis for this is that [provide a technical basis; for example, testing of the replacement sump screen in the flume accurately modeled the local velocity and field that would be expected in the plant, along with obstacles in the flow field approach to the replacement sump screen]. Under these conditions, testing demonstrated that about [YY] % of the fines would settle out on the reactor containment building floor prior to reaching the replacement sump screen. The debris transport calculations conservatively credited a settle-out of [ZZ] % of the fines prior to their reaching the replacement sump screen.

3e.6 Summary of Debris Transport Calculations

Debris transport logic trees were developed for each type of debris generated for [Plant Name]. The logic trees were used to determine the total fraction of debris that would reach the sump screens in each of the postulated break locations considered. The break locations and the associated results are summarized below.

LBLOCA in [Location]

RMI Debris:

- The logic tree for small pieces of RMI insulation debris shows that the overall transport fraction for small RMI would be 67%.
- The logic tree for large pieces of RMI insulation debris shows that the overall transport fraction for large RMI would be 77%.

Low Density Fiberglass Debris:

- The logic tree for individual fiberglass fibers shows that the overall transport fraction for the individual fibers would be 97%.

- The logic tree for small pieces of fiberglass insulation debris shows that the overall transport fraction for small fiberglass would be 65%.

- The logic tree for large pieces of fiberglass insulation debris shows that the overall transport fraction for large fiberglass would be 75%.

- The logic tree for large pieces of fiberglass insulation debris with jacketing intact shows that the overall transport fraction for intact pieces of fiberglass would be 73%.

Miscellaneous Fine Debris Inside the ZOI

- Since other miscellaneous fine debris, including Min-K™ and coatings inside the ZOI, would transport the same as the individual fiberglass fibers (with the exception of Thermo-Lag™), the overall transport fraction for this debris would be 97%.

- The transport of the Thermo-Lag™ debris would be 0%.

Latent Debris

- The logic tree for latent fiberglass, dirt and dust debris shows that the overall transport fraction for the latent debris would be 85%.

Unqualified Coatings Debris Outside the ZOI

- Since all of the unqualified coatings debris failing outside the ZOI was assumed to reach the pool, and the recirculation transport fraction for this debris is 100%, the overall transport fraction would also be 100%.

The debris transport results for [Plant Name] for each of the break scenarios considered are summarized in the following tables. The percentages shown are the transport fractions of materials that would reach the replacement sump screen for the postulated high energy line break.

Table 3 is an example of the debris transported to the replacement sump screen for a postulated large break LOCA.

Table 3: LBLOCA at [Location]

Debris Type	Debris Size	Quantity Generated	Transport Fraction	Quantity at Sump Screen
NUKON™	Fines	300 ft^3	97%	291 ft^3
	Small Pieces	1,000 ft^3	65%	650 ft^3
	Large Pieces	500 ft^3	75%	375 ft^3
	Intact Pieces	500 ft^3	75%	375 ft^3
	Total	2,300 ft^3	73.5 %	1,681 ft^3
Thermo-Lag™	Total (Fines)	25 lb_m	0%	0 lb_m
Coatings Inside ZOI	Total (Fines)	500 lb_m	97%	485 lb_m
Coatings Outside ZOI	Total (Fines)	1,100 lb_m	100%	1,100 lb_m
Coatings Outside ZOI	Total (Chips)	1,100 lb_m	100%	1,100 lb_m
Latent Particulate	Total (Fines)	200 lb_m	85%	170 lb_m
Latent Fiber	Total (Fines)	0.3 ft^3	85%	0.3 ft^3
Miscellaneous Debris	Total	450 ft^3	100%	450 ft^3

Present the transport fractions and total debris transported to the replacement sump for all break locations evaluated in a manner similar to that shown in Table 3, above.

Table 3f Illustrative Example – Head Loss and Vortexing

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

Table 3g Illustrative Example – Net Positive Suction Head (NPSH)

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

The engineered safety feature (ESF) systems include two trains of emergency cooling pumps. Each train consists of one high pressure injection (HPI) pump, one low pressure injection (LPI) pump, and one containment spray (CS) pump. Both ESF trains are normally aligned to the refueling water storage tank (RWST), and can be aligned to the ECCS sump by manual operator actions once a pre-determined minimum water level in the RWST has been reached.

System response is determined by break size and resulting reactor coolant system (RCS) and containment pressure characteristics. The HPI pumps and LPI pumps are actuated when RCS pressure decreases to 1625 psig and 500 psig, respectively. Similarly, the CS pumps are actuated when containment pressure increases to 30 psig. Once actuated, automatic flow control valves control LPI flow to 3000 gpm per train. Depending on break size, CS pump actuation may or may not occur. Once actuated, automatic flow control valves control CS flow to 1500 gpm.

For a small break LOCA, the rate of RCS depressurization will be slow and therefore create a delay between HPI and LPI actuations. Due to the relatively low shutoff head of the LPI pumps, LPI flow to the RCS will not begin until the RCS depressurizes to approximately 200 psig. For a large break LOCA, rapid RCS depressurization, and concurrent containment pressurization, will cause HPI, LPI, and CS actuation early in the event. For the bounding large break LOCA, RCS pressure will be sufficiently low to allow full HPI and LPI, resulting in most rapid depletion of the RWST and therefore earliest switchover to ECCS sump recirculation.

For both small and large break LOCAs, the setpoints for LPI and CS flow control are manually reduced to 2000 gpm and 1200 gpm, respectively, as RWST level decreases to a predetermined level. The HPI pumps (if HPI termination criteria are not satisfied) and CS pumps are aligned to take suction from the discharge of the LPI pumps (piggyback operation). Transfer to ECCS sump recirculation is then accomplished by opening the ECCS sump suction valves and closing the RWST suction valves. Both LPI pumps take suction from a common ECCS sump.

Net-positive suction head (NPSH) calculations were performed to establish the ECCS and CS pump NPSH margins in the absence of the ECCS strainers and collected debris (i.e., pump NPSH margins were calculated by subtracting the NPSH available from the NPSH required, without including headloss through the ECCS strainer and collected debris).

HPI, LPI and CS pumps are secured manually only if specific termination criteria are met. Therefore, the design basis NPSH analyses assume that pumps in both trains are operating concurrently throughout the injection and recirculation phases of emergency cooling. Failure of a single pump or complete pump train to operate results in decreased headloss across the common sump screen and therefore these failures have a positive effect on NPSH margin (same or greater required NPSH and increased available NPSH). The most limiting active failure was determined to be failure to reduce flow from LPI "A" pump prior to transferring to ECCS sump recirculation. The results from the design basis NPSH case and the single active failure NPSH case are reported in Table 3.g-1 below. Since only the LPI pumps take suction directly from the ECCS sump, only the LPI pump NPSH values are reported. The LPI pump NPSH required was determined by the pump manufacturer based on a 3 percent decrease in developed pump head. The minimum NPSH margin is for LPI "A" pump and occurs in conjunction with failure to reduce flow to the pump prior to transferring to ECCS sump recirculation.

Table 3.g-1

Pump	Case	NPSHA (ft)	NPSHR (ft)	NPSH Margin (ft)
LPI "A"	Design Basis	22.4	19.0	3.4
LPI "B"	Design Basis	22.2	19.0	3.2
LPI "A"	Failure to reduce LPI "A" flow	22.0	20.0	2.0
LPI "B"	Failure to reduce LPI "A" flow	22.0	19.0	3.0

These margins were used to determine acceptability of the headloss across the debris-laden ECCS strainer during the recirculation mode of emergency core cooling following a postulated LOCA.

The NPSH available calculations were performed using assumptions consistent with guidance in NEI 04-07 and its associated SER for minimizing the effect of containment over-pressure on the NPSH calculation results. For the minimum NPSH margin case, no containment overpressure was credited (i.e., containment pressure was assumed to equal the saturation pressure corresponding to the sump water temperature). In examining the potential for release of gas from the fluid as it passes through the ECCS strainer, it was assumed that the containment dry air pressure remained constant; however, no credit was taken for an elevated containment pressure resulting from post-LOCA heating of the air. This approach is consistent with the guidance of NEI 04-07.

NPSH available calculations were performed for saturated sump water at a temperature of 212°F. The basis for selecting this temperature is provided in the following two paragraphs.

First, the minimum post-accident containment pressure was set equal to the minimum pressure allowed by Technical Specifications (12.7 psia). The saturation temperature corresponding to this minimum containment pressure (204.7^{o}F) was then established as the limiting sump pool temperature for purposes of determining NPSH available. For sump pool temperatures above the limiting temperature, containment pressure is set equal to the saturation pressure (i.e., vapor pressure) corresponding to the sump pool temperature. For sump pool temperatures at or below the limiting temperature, containment pressure is set equal to the minimum post-accident containment pressure (12.7 psia).

As sump pool temperature increases above the limiting temperature, water viscosity decreases. This results in decreased headloss due to piping friction losses and flow through the debris bed (in both cases assuming constant volumetric flow). Since for this case containment pressure is set equal to the saturation pressure corresponding to sump pool temperature, the effect of increased sump pool temperature is an <u>increase</u> in NPSH available (due to decrease in headloss).

As sump pool temperature decreases below the limiting temperature, the corresponding saturation pressure (i.e., vapor pressure) decreases below the minimum post-accident containment pressure, resulting in a subcooled sump pool; this effect increases NPSH available. However, as sump pool temperature decreases below the limiting value, water viscosity increases. This results in increased headloss due to piping friction losses and flow through the debris bed (in both cases assuming constant volumetric flow); this effect decreases NPSH available. A parametric evaluation was performed to determine the impact of decreasing sump pool temperature on headloss. This evaluation demonstrated that the relatively small increase in headloss was overwhelmed by the sump pool subcooling effect (i.e., sump pool saturation pressure decreasing below the minimum post-accident containment pressure). For example, as the sump pool temperature decreases from 204.7^{o}F to 125^{o}F, the debris headloss increases by less than 0.5′. Over this same temperature range, NPSH available increases by approximately 23′ due to subcooling of the sump pool. Therefore, the net effect of decreased sump pool temperature is also an <u>increase</u> in NPSH available.

The preceding discussion demonstrates that the limiting NPSH available occurs at a sump pool temperature of 204.7^{o}F.

No credit was taken for the hot channel correction factor that would tend to decrease the NPSH required at the assumed (elevated) temperature.

NPSH available calculations were prepared based on hydraulic models of the systems aligned for ECCS sump recirculation per plant procedures. Different configurations were modeled and the system configuration resulting in the highest sump flow rate was used for sizing of the ECCS sump strainers. The configuration resulting in the smallest NPSH margin was used to determine acceptable screen headloss. These calculations use Equation 3-14 of Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe" to determine the head loss due to frictional resistance in the piping and line losses due to other components. Resistance values for piping and components were also taken from Crane Technical Paper No. 410.

The minimum water level in containment at the start of transition to recirculation was calculated to be 223.6 ft elevation for a small break LOCA and 223.9 ft for a large break LOCA. The floor of containment is at elevation 221′; thus, the minimum pool depth is 2.6 ft for a small break LOCA and 2.9 ft for a large break LOCA. The small break LOCA minimum water level is conservatively assumed for all cases.

The transition to ECCS recirculation begins when the RWST is drained to approximately 27%, at which point the assumed 223.6 ft water level is reached. Transition to ECCS recirculation is complete when the RWST is drained to approximately 9%. Therefore, during recirculation, the water level will increase above the assumed 223.6 ft level; however, no credit is taken for the water injected from the RWST during the transition to recirculation.

The water-level calculation first determines the mass of water injected into containment, then subtracts out the mass of water that is diverted away from the sump, i.e. held up. The remaining mass of water is converted to a pool level. The water level calculation conservatively accounts for the sources of water on the containment floor and for the water holdup mechanisms and associated volumes. Determination of the minimum water level accounted for water holdup in the following locations:

- Spray water droplets in the containment atmosphere. This assumes maximum spray flow falling from the highest point in containment to the containment floor.
- Water flow in transit to the pool from the pipe break. This assumes maximum RHR flow falling from the top of the surge line to the containment floor.
- Condensation on containment surfaces. This includes a non-flowing layer of condensation on all of the surfaces identified in the containment heat-sink calculation, except for the containment wall and dome, of 0.003 inches in thickness as well as a flowing layer of condensation on the containment wall and dome.
- Depressions in the pump bay floors (drains are assumed to be blocked).
- The refueling cavity (drain is assumed to be blocked).
- Normally dry containment spray ring header and risers. Similarly, the calculation assumes that the suction piping leading from the ECCS sumps to the LPI pumps is initially empty, although this piping is actually kept full to minimize the likelihood of air entrainment to the pumps upon initiation of recirculation.
- The calculation also assumes 300 cubic feet of miscellaneous holdup.

The inputs to the water level calculation are biased toward minimizing the containment water level. The calculation uses the RWST, the accumulators, and the chemical spray addition tank (CSAT), as water sources. The RWST is assumed to initially be at the low-level alarm setpoint, and as injection proceeds, the level is assumed to drop to the low-low alarm setpoint, at which point the transition to recirculation begins. The total volume of water injected from the RWST is 37,322 cubic feet. Each of the three accumulators is assumed to be at the Technical Specification minimum level, and the total volume of water added to the containment floor from the accumulators is 2,982 cubic feet. The CSAT is assumed to initially be at the Technical Specification minimum water volume of 3,268 gallons, and the associated Containment Spray Chemical Additive Valves shut once the level of the CSAT reaches the low-level alarm setpoint of 2%. Thus, a total of 420 cubic feet of water is added to the containment floor from the CSAT. However, in determining the minimum water level in containment, only 39 cubic feet is used, as this is the minimum amount educted from the CSAT at the time the containment atmosphere reaches its peak temperature, thereby maximizing the quantity of water vapor in the containment atmosphere. Each water source is assumed to be at its respective maximum temperature to minimize the mass of water injected into containment.

The water level calculation assumes that structural components will displace water, resulting in a higher pool level. These structural components include the primary shield wall; the secondary shield wall (including the straight sections of the wall, the refueling cavity support walls, and the associated air plenums), the bioshield wall and the associated ribs; the reactor coolant pump (RCP) and steam generator (SG) pedestals; the incore sump curb; the recirculation sump structures and the associated curbs; the refueling cavity leakage enclosure; the walls around the reactor coolant drain tank (RCDT) pumps and heat exchanger; and the twenty-two steel columns adjacent to the containment liner. The pedestals for the airborne radiation removal units, the non-safety containment fan coolers, the RCDT pumps and heat exchanger, and the HVAC equipment on the 221′ elevation are all six inches high and are also credited with displacing water. Each of the airborne radiation removal units and the non-safety containment fan coolers are credited with displacing three cubic feet of water, and the primary shield cooling fans are credited with displacing one cubic foot of water.

The curbing around the elevator pit, the elevator platform and associated ramp, and the elevator proper are credited with displacing water. The elevator proper is credited with displacing ten cubic feet of water, which is reasonable given the elevator equipment inside the elevator pit.

Table 3h Illustrative Example – Coatings Evaluation

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

<u>Summary of types of coating systems used in [plant] containment</u>

The primary field-applied ["DBA-qualified" **OR** "Acceptable"] coatings systems in containment for [plant] are [CZ-11/Phenoline 305] for steel and [Nutec 11S / Nutec 11 / Nutec 1201] for concrete.

In addition, the following ["DBA-qualified" **OR** "Acceptable"] coatings systems have been used for steel maintenance coating work: [Carboline 801, Carboline 890, and Amerlock 400]

Also, the following ["DBA-qualified" **OR** "Acceptable"] coatings system has been used for concrete maintenance work: [Starglaze 2011S / Starglaze 2011 / Carboline 890]

DBA-unqualified coatings systems include inorganic zinc, epoxy, silicones and alkyds.

<u>Bases for assumptions made in post-LOCA paint debris generation and transport analysis</u>

The post-DBA debris evaluations of all coatings were all based on NEI-04-07 and/or testing as discussed below.

The debris generation assumption made for ["DBA-qualified" **OR** "Acceptable"] coatings in the zone of influence of the LOCA is based on testing performed on representative coating systems. A spherical ZOI of 4D for epoxy was selected based on………
[WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA Qualified/Acceptable Coatings", Revision 0 dated June 2006.] This testing concluded that a spherical ZOI of 4D is conservative for the ["DBA-qualified" **OR** "Acceptable"] epoxy coatings used by [plant].]
AND/OR
[ZOI evaluation of the specific ["DBA-qualified" **OR** "Acceptable"] containment coatings at [plant] performed using the results of the Coatings Performance Tests conducted by FPL and Areva NP (JOGAR Testing). This evaluation concluded that a spherical ZOI of 4D is conservative for the ["DBA-qualified" **OR** "Acceptable"] epoxy coatings used by [plant].]

[NOTE: For plants with untopcoated IOZ, a similar discussion of the ZOI used and its basis is required. For example, the WCAP-16568-P recommended ZOI for untopcoated inorganic zinc primer is 5D]

For debris generation and transport analysis, 10 micron particles were assumed for ["DBA-qualified" **OR** "Acceptable"] coatings within the 4D ZOI. ["DBA-qualified" **OR** "Acceptable"] coatings outside the 4D ZOI were not assumed to fail.

For debris generation and transport analysis, 10 micron particles were assumed for DBA-unqualified coatings within a 10D ZOI. In addition, 100% of the DBA-unqualified and degraded coatings outside the 4D ZOI were assumed to fail as 10 micron particles [except where based on testing and plant specific conditions as described below].

Testing performed for Comanche Peak Steam Electric Station by Keeler & Long [Keeler and Long Report No. 06-0413, "Design Basis Accident 'Testing of Coating Samples from Unit 1 Containment, TXU Comanche Peak SES," has been reviewed and found applicable to the degraded DBA-qualified epoxy and inorganic zinc coatings applied at [plant]. In the test, epoxy topcoat / inorganic zinc primer coating system chips, taken from the Comanche Peak Unit 1 containment after 15 years of nuclear service, were subjected to DBA testing in accordance with ASTM D 3911-03. In addition to the standard test protocol contained in ASTM D 3911-03, 10 µm filters were installed in the autoclave recirculation piping to capture small, transportable particulate coating debris generated during the test.

The 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 headloss analysis of inorganic zinc. The data in this report also showed that DBA-qualified epoxy that has failed as chips by delamination tend to remain chips in a LOCA environment. The data showed that almost all of the chips remained larger than 1/32 inch diameter. Therefore, a chip diameter of 1/32 inch may be used for transport for Phenoline 305 epoxy coatings shown to fail as chips by delamination. Carboline Phenoline 305, according to manufacturer's publish data sheets and MSDS's, is conservatively representative of the other DBA-qualified/Acceptable epoxy coatings found in US NPP's, including Mobil 78, Mobil 89, Amercoat 66, Keeler & Long 6548/7107 an d Keeler & Long D-1 and E-1. [Ref. letter from Jon Cavallo, Vice President, Corrosion Control Consultants and Labs Inc., dated September 20, 2007]

For OEM coatings, Design Basis Accident Testing of Pressurized Water Reactor Unqualified Original Equipment Manufacturer Coatings, EPRI 1011753 dated September 2005, was used to determine that 10 microns is a very conservative assumption for particle sizes. None of the OEM coatings failed as chips. Therefore, 10 micron particle sizes were used for transport and head loss analyses. This report also showed that, on average, much less than half of OEM coatings detached and failed during testing. Based on the EPRI test results and the conservative assumption of 10 micron particle size, 100% failure of all OEM coatings is overly conservative.

(plant) has determined based on the review of the EPRI Report No 1011753 , September 2005 for Original Equipment Manufacturers (OEM) unqualified coatings that (plant) could not reduce the failure percentage across the board for all non qualified OEM coatings. It has been determined based on the review of the EPRI report and plant specific coating types a reduction in the failure percentage for the [epoxy (list specific type)] could be justified. The failure percentage for [epoxy (type specific)] is [50%]. The failure percentage bounds the worst performing sample for this type in the test data. [NOTE: Also list any plant specific testing that was conducted on OEM coating to determine failure percentage.]

Therefore, the following failure percentages were assumed for OEM coatings.

Epoxy – [50%]
Inorganic Zinc – [100%]
Akyds – 100%
Urethane – 100%
Other – 100%

No debris was included in transport and head loss analysis for unqualified coatings outside the ZOI that are a) within an inactive sump, b) covered by intact insulation, or c) otherwise isolated from spray and transport to the sump.

Head Loss Testing

For head loss testing, representative surrogates with similar density, size, and shape characteristics to the debris generation assumptions above were selected.

[NOTE: Plants with low fiber will need to address head loss testing with chips in accordance with the SE for NEI 04-07]

For coating debris from epoxy, phenolics, silicones, enamel and alkyds specified as powder, [#325 walnut shell flour] which has similar density, size, and shape characteristics to these coatings was utilized. For epoxy and phenolic coating debris specified as chips, the surrogate was formed from the dry film of [Carboline® Carboguard® 890/891].

For coating debris from inorganic zinc, the surrogate used was [tin powder with a particle size range of ~10 to 44 microns]. [Tin powder] has similar density, size, and shape characteristics as inorganic zinc. The particle size selected was based on the Keeler and Long Report No. 06-0413 as discussed above.

Ongoing Containment Coating Condition Assessment Program

The acceptability of visual inspection as the first step in monitoring of Containment Building coatings is validated by EPRI Report No. 1014883, "Plant Support Engineering: Adhesion Testing of Nuclear Coating Service Level 1 Coatings," August 2007. Monitoring of Containment Building coatings is conducted at a minimum, once each fuel cycle in accordance with [plant] procedures based on ASTM D 5163-05a, Standard Guide for Establishing Procedures to Monitor the Performance of Coating Service Level I Coating Systems in an Operating Nuclear Power Plant. Monitoring involves conducting a general visual examination of all assessable coated surfaces within the Containment Building, followed by additional nondestructive and destructive examinations of degraded coating areas as directed by the plant Protective Coatings Specialist. Examinations and 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.

Table 3i Illustrative Example – Debris Source Term Refinements

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

Table 3j Illustrative Example – Screen Modification Package

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

The intent of the modification was to perform the hardware changes required to bring (plant) into full resolution with NRC GSI-191. This modification replaced the existing Metcon grating/screens for the (plant) B-Sumps located outside the missile shield walls on the basement floor of the Unit 1 and Unit 2 Containment buildings. To prevent debris from entering the open sump, a standard floor grate that extends from the floor in an A-frame shape with 3/4 x 3-11/16 inch openings was provided to completely cover the sump inlet. The grate provided approximately 49.2 ft^2 of available flow area. Due to the size of the screen openings, only large pieces of debris were prevented from entering the sump. In addition, the sump is surrounded by a six-inch high curb which is used to prevent sediment from entering the pit. The modification installed a passive, safety-related (model #) ® Strainer assembly engineered and manufactured by (vendor). The strainer arrangement for each of (plant) Units 1 and 2 consists of two strainer trains of (model #) ® Strainer modules connecting to a common sump pit cover plate designed to form a suction chamber in the existing sump pit. The modifications were installed on Unit 1 and Unit 2 during the 2006 refueling outages.

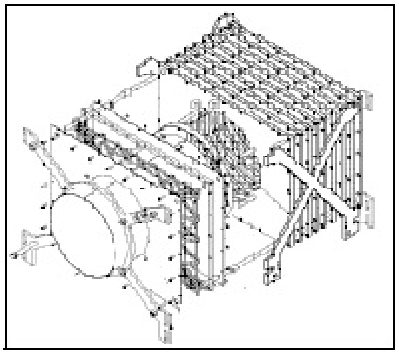

Figure 1 Single Module

The effective surface area of the new strainer for each train is 413.65 ft^2, for a total of 827.3 ft^2. This will reduce flow velocity through the screens to 0.014 fps. The strainer configuration is designed to limit the head loss to 10 feet during post-LOCA design conditions.

There are 10 modules in each strainer train (Figure 3), a core tube, and mounting tracks. The modules are essentially identical with the only difference being the hole sizes in the core tube. Each module is independently supported. The modules are connected with thin gauge stainless steel bands that are used to prevent debris from entering the system between the two modules. This connection permits relative motion in the axial direction as the core tube can slide relative to the stainless steel bands.

Each module (Figure 1) is made of stainless steel perforated plate with hole-diameter of 0.085 inch. The perforated sheets are riveted together along the outside edge and shop welded to a core tube along the inner edges. The modules are located approximately 3 inches above the containment floor. As such, the six-inch high curb surrounding the sump no longer provides a barrier to prevent sediment from entering the strainers. The sump is now totally enclosed by the sump pit cover plate preventing material from falling directly into the sump without passing through the strainer assemblies (Figure 2).

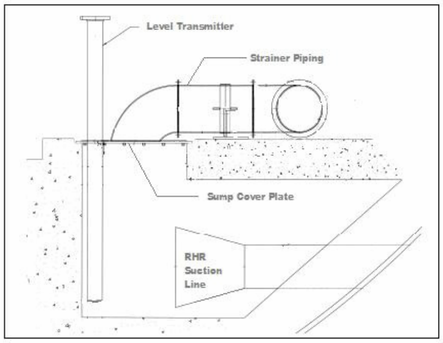

Figure 2 Containment Sump B Side View

The core tube is a 12 inch diameter, 16-gauge, stainless steel pipe. The core tubes of each module are connected together by means of a coupling sleeve fitted over the core tubes and secured by a latch. The core tube has "windows" cut in the wall to admit flow of strained water from the inside of the perforated sheets. The modules are pin connected to a mounting track, which in turn is bolted to the containment slab. The mounting track is made of structural shapes: angles and plates. The strainer design allows for disassembly, replacement of modules, or addition of future modules as needed. A 14 inch schedule 10 stainless steel pipe, double elbows (one vertical, one horizontal with an intermediate straight piece) and 14"x12" eccentric reducer sloped upwards from the first module delivers the strained water into the sump by penetrating through the sump cover plate. The vertical elbow attached to the sump cover plate is removable to allow access into the sump during outages for inspection and testing.

Two 6-inch pipe-stands for the B-Sump level transmitters in each of Unit 1 and Unit 2 have been relocated to the southeast and southwest corners of the sump cover plate and supported on the 6-inch wide curb 1'-3" above the sump bottom and restrained using new seismic restraints. The standpipe has seven 1-inch diameter holes above the bottom of the strainer core tube that will be sealed to prevent ingestion of air into the sump. The remaining open holes are covered with screens containing 0.063 inch square openings, which are less than the new strainer perforations. These level instruments are considered backups and would be used only as indication to inform the operator that there was sufficient level in the sump to switch from the injection to recirculation phase.

Other changes associated with this modification included capping abandoned Waste Liquid Disposal Pipes located in the sump, and relocating and/or reconfiguring several existing components to remove interferences associated with the new strainer installation.

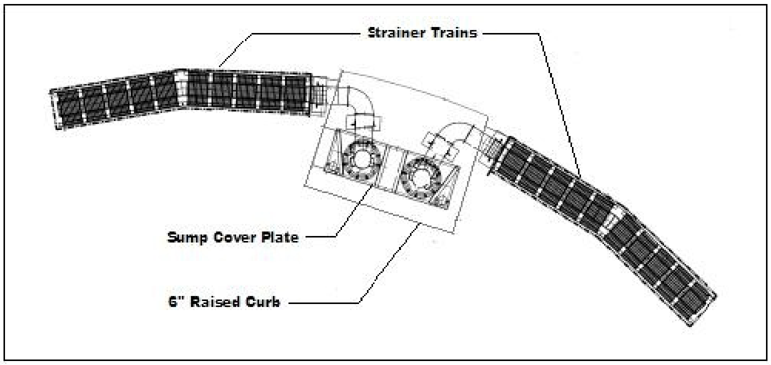

Figure 3 Plant Strainer Assembly Top View

Table 3k Illustrative Example – Sump Structural Analysis

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

The modified Safety Injection Sump strainer assembly for (*Plant Name*) is located in the same general area as the previous strainer screens. Sketches showing the location of the modified strainer assembly are attached to this report.

The modified Safety Injection Sump strainer assembly was structurally analyzed and found to meet all design requirements given in the Final Safety Analysis Report (FSAR) for (*plant name*). The load combinations used in this analysis are the same as already defined for structures in safety related applications at (*plant name)*.

A structural evaluation was performed to qualify the new strainers installed in the Containment Recirculation Sumps. This evaluation was by analysis, and included the strainer modules as well as the supporting structures associated with the strainers. The evaluation was performed using a combination of manual calculations and finite element analysis using commercially available computer codes. Th~~e~~ evaluations followed the requirements of the plant specific design specifications. The strainers are designed for the following loads:

- Seismic loads —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 (plant name). The structures are considered “Bolted steel structures” and the damping values for seismic loads are taken from Regulatory Guide 1.61 as 4% for the OBE and 7% for the SSE.
- Live Loads – Live loads include the weight of the debris, which accumulates 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 themselves 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, the seismic supports are gapped leaving enough of a gap to accommodate the thermal growth of the strainers and their supports without restraint. The design temperature for the strainers was taken equal to the maximum water temperature of XXX°F. The maximum air temperature inside containment can reach as high as XXX°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, the use of the maximum water temperature for material properties and thermal expansion is appropriate

[The references used in the analysis, the design inputs used, and the loadings used in the analysis are defined in the structural analysis separately provided to the NRC for their information.] *Plant specific response.*

(*Note to all – If you are providing a copy of your structural analysis to the NRC for their information, make sure that you have a proprietary agreement in place with them. Most vendor supplied analyses are proprietary documents. If the NRC receives these without any precautions or agreements, they possibly could be placed in the public document files for your plant. Plants that have undergone audits have reached an agreement to provide the proprietary documents to the NRC for their review, with the documents either being returned to the utility, or destroyed upon completion of the NRC reviews. While a summary of the design inputs, references, and loadings can be provided to the NRC as part of this summary, it is probably much better to simply provide the NRC the analysis itself.)*

[Pipe Whip and jet impingement were reviewed for their impact on the modified strainers, and were found not to be a concern. The strainers are locationed in areas where there are no pipe whip loads or missile loads on the strainers.] *Plant specific response.*

(*For plants with strainers in a jet impingement area)*
The locations were also picked so any jet impingement loads are low enough that the strainers are capable of withstanding them. This is documented in the structural analysis provided to the NRC for information.

(*For plants with strainers NOT in a jet impingement path)*
The new strainer locations were picked so that there are no jet impingement loads that could strike the strainers or their related equipment.

Plant procedures were revised to require that the modified Safety Injection Sump strainer assembly be inspected prior to containment closeout at the end of an outage. This inspection is being done as part of Operations inspection for cleanliness, loose items, etc. If any damage is found, the Operators performing the inspection are instructed to contact Design Engineering to evaluate the damage.

In summary, (*plant name*) has evaluated the modified sump strainers and shown that all design requirements are met.

Table 3l Illustrative Example – Upstream Effects

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

As part of the Sump Inventory, Debris Generation, and Debris Transport Analyses, an evaluation of flowpaths necessary to return water to the recirculation sump strainer was performed [site specific evaluation number & title – See Prairie Island Audit Report]. This evaluation was performed in accordance with the recommendations contained within NEI 04-07 to identify those flowpaths that could result in the holdup of water not previously considered. These flowpaths included those areas into which Containment Spray and RCS break flow would enter. This evaluation determined that, with the exception of [the refueling cavity drains, inter-compartment openings that have installed gates, or debris interceptor(s) installed to prevent the transport of large pieces of debris to the recirculation sump strainer], all other water return flowpaths have sufficiently large openings to prevent the holdup of significant quantities of water that could challenge the containment sump minimum water level analysis.

As part of the containment water level analysis [site specific calc number & title], hold-up volumes were calculated for all spray return pathways that due to physical design features such as curbs, toe plates, or recessed areas (fuel transfer upender pit) would function to reduce the quantity of water available in the containment sump pool. The containment water level analysis was also compared against the Debris Generation and Debris Transport analyses [site specific calc numbers & titles] to ensure that no new hold-up volumes were created as a result of debris blockage of the required flowpaths.

The containment water level analysis also determined that the post-LOCA minimum containment water level during the recirculation phase to ensure sufficient water level was available to prevent vortexing or excessive air entrainment, as well as ensuring adequate NPSH available for the ECCS and CSS pumps.

The required flowpaths for return of water to the containment sump pool include the refueling cavity drains, the stairwells connecting the various elevations of containment, and the openings (doorways) within the bioshield.

The reactor cavity drain(s) is a [single 4-inch] drain pipe that is protected by a debris barrier that is sufficiently large [provide dimensions and relationship to the drain] to prevent any credible debris that may be generated as a result of the break from blocking this flow path.

[Additional choke points were identified at the openings in the bioshield that have gates installed to prevent inadvertent access during plant operations. To ensure that these gates would not function as a debris interceptor and hold up necessary water volume for the sump, portions of the lower screen panels were removed as recommended by the Debris Transport analysis.]

As part of the physical modifications installed in the plant to resolve GSI-191, [debris interceptors, debris curbs, etc] were installed to limit the quantity of large debris that could interact with the recirculation sump strainer. The design of this [interceptor type] considered the potential for holding up, or choking, the necessary water flow to the sump strainer. The design ensured that even if fully blocked by large debris, sufficient flow area would be available over the top of the [device] to provide the required minimum water level and flow to the recirculation sump strainer.

As a result of the evaluations performed and physical changes completed, [plant name] has determined that the upstream effects analysis provides the necessary level of assurance that the required volume of water will be available to the recirculation sump for the function to meet the applicable requirements as set forth in NEI 04-07 and GL 2004-02.

Table 3m Illustrative Example – Downstream Effects

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

5.3 Downstream Effects.

5.3.1 Downstream Effects - Components and Systems.

[Plant] has developed the [five] calculations listed below to address downstream effects. These calculations were developed [in accordance with, (or alternately list any deviations or exceptions taken)] PWROG WCAP-16406-P, Rev. 1 [ref. x].

- Calculation [#1], [Ref. #1]
- Calculation [#2], [Ref. #2]
- Calculation [#3], [Ref. #3]
- Calculation [#4], [Ref. #4]
- Calculation [#5], [Ref. #5]

[Plant] system line-ups, mission times, flows and pressures used to bound downstream evaluations are described in the applicable downstream effects calculations listed above. The calculations confirm that ECCS operation during small-break, medium-break, and large-break LOCAs is adequate to meet the requirements of the [Plant] accident analyses.

The calculations confirm that there is no significant air entrainment with the ECCS that would either impact ECCS pump operation or cause air pockets in ECCS piping, and the potential for waterhammer and slug flow is low.

The calculations evaluate the downstream effects of debris ingestion of the auxiliary equipment in the [plant] plant including the valves, pumps, heat exchangers, [cyclone separators,]orifices, spray nozzles, and instrumentation tubing, following the methodology in Reference x[, with the exceptions/deviations listed above]. The effects of debris ingested through the containment sump strainers during the recirculation mode of the ECCS and CSS include erosive wear, abrasion and potential blockage of equipment and flow paths. The calculations also document an assessment of changes in system or equipment operation caused by wear, including an evaluation of pump hydraulic performance due to internal wear.

Based on the potential debris-induced seal leakage into the auxiliary building, calculation [#6, Reference #6] evaluated the resultant affects on equipment qualification and room habitability. [The consequences of leakage into the auxiliary building are bounded by the [Plant] accident analyses.]

5.3.2 Downstream Effects - Fuel and Vessel.

[Note: This section may need to be revised based on the long term cooling WCAP being reviewed currently with the staff.]

[Plant] used the methodology of WCAP-16406-P, Rev. 1 [Ref. #] for the evaluation of potential core blockage following a hot leg or a cold leg break. With the low flow velocity calculated in the reactor vessel lower plenum, particulate debris with a density that is heavier than water will settle in the lower plenum and not be passed into the core. Fibrous debris with a density approximately the same as water would be carried along with the recirculated sump water but would be filtered by the sump strainers and by screens located at the inlet to the fuel bundles.

[An additional detailed evaluation of long-term cooling considering particulate and chemical debris in the recirculation fluid was also completed (Reference WCAP-16793P).]

Calculation #x (Ref. x) provides the methodology for determining the amount of particulate debris which flows into the reactor vessel with the ECCS water (Ref. x). It is expected that any small particles of RMI, concrete debris, latent containment debris and all but the smallest coating particulates that pass through the sump screen and reach the reactor vessel will settle in the lower plenum of the reactor vessel. The total volume of particulate and coatings debris which is calculated to settle in the reactor vessel is approximately [xx] cubic feet (Ref. x). The volume of the reactor vessel lower plenum below the core is much larger (approximately [xx] cubic feet) so particulate and coating debris at [Plant] does not impact flow in the lower plenum.

Reference [xx] calculates that [xx] cubic feet of [mineral wool, others] and latent fibrous debris will be formed within the [Plant] containment following a large break LOCA. The reference [xx] calculation conservatively assumes that 100% of the fibrous debris is transported to the containment sump.

Even though some or most of the fibrous debris is expected to be retained on the sump screens, the reference [xx] calculation assumes that all such debris passing through the strainer reaches the core.

A sump screen efficiency of [xx%] for filtration of fibrous debris was used based on scale model screen testing described in reference [xx]. The [Plant] sump screen testing program was based on the screen velocity which would occur for a flow rate of [xx] gpm. This flow rate would be appropriate for operation of one high pressure ECCS pump and one containment spray pump in each engineered safety features train. [Address the potential event that the low pressure ECCS pump for that train inadvertently did not trip.] [Also address bypass flow debris quantities associated with tests.]

The acceptance criterion of a fibrous debris bed thickness is no more than 0.125 inches across the core inlet. This acceptance criterion is based on [pressure drop studies for BWR strainer blockage concerns in NUREG/CR-6224 (Ref,xx), and appropriate additional justification]. This acceptance criterion is conservative because it is expected that low, non-uniform flow rates would likely exist at the core inlet during the post-LOCA long-term cooling period, making the formation of a uniform compact fiber bed at the core inlet unlikely.

Using the methodology of WCAP-16406-P, the reference [xx] calculates a fiber bed thickness at the core inlet of [xx] inches following a postulated cold leg break and [xx] inches following a hot leg break (ref. xx). These thicknesses are for the latest time of switchover from cold leg recirculation to hot leg recirculation, which is [xx] hours at [Plant]. [Address the operating condition of one low pressure ECCS pump for an operating train inadvertently not tripped.]

To prevent excessive concentration of boric acid within the core following a large cold leg break, the existing emergency procedures at [Plant] instruct operators to [address hot leg recirculation or other methods]. Since the location of the break will not be known to the plant operators, [hot leg recirculation] would begin [between x to x] hours after the accident at [Plant] regardless of break location.

Since hot leg injection will not begin until at least two hours after the pipe break occurs, there is the opportunity for a considerable amount of the debris to be filtered out or to settle from the water that flows to the top of the core. An analysis (Ref. 2) based on the methodology of WCAP-16406-P indicates that after a time of [x] hours, the concentration of fibrous debris in the recirculating fluid will be about [one half] of the initial value.

In addition to locations at the core inlet and exit, other possible locations for blockage within the reactor vessel internals which might affect core cooling were assessed (Ref. x). The smallest clearance was found to be [xx] inches. This dimension is approximately a factor of [xx] greater than the dimension of the strainer holes in the containment sump screen.

[Address other unresolved issues involving the potential for core internal heat transfer degradation between the fuel rods and the coolant in the presence of debris and chemicals in the recirculated sump water. See WCAP-16793P.]

Table 3n Illustrative Example – Chemical Effects

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

Table 3o Illustrative Example – License Amendments

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

Table 3p Illustrative Example – Foreign Material Control Program

The following example is provided as an illustration of level of detail only. Specifics of individual plant approaches vary and will affect the level of detail to be included:

To maintain the required configuration of the containment recirculation function that supports the inputs and assumptions utilized to perform the mechanistic evaluation of this function, [plant name] has implemented programmatic and process controls as described below.

Plant procedures, programs, and design requirements were reviewed to determine those that could impact the analyzed containment or recirculation function configuration. These reviews resulted in the identification of those documents that required revision or development of new documents to ensure maintenance of the inputs and assumptions into the future.

The Engineering related documents that were revised or developed to support and maintain the required configuration control for maintenance of the inputs and assumptions that support the GSI-191 issue resolution are:

- Design Specification [number], Requirements for Materials in Containment – this specification is considered as the master document for determining the acceptability of materials for use in containment for preventing changes to the debris source term.

- Electrical Design Specifications and Standards for identification and color coding of instrumentation, control, and power conductors, conduits and cable trays with specific requirements for those installations inside containment.

- Design Control and Design Change Reference procedures to provide for detailed analysis and evaluation of temporary or permanent modifications to SSCs inside containment, or in the required downstream recirculation flowpaths, to ensure the inputs and assumptions that support the GSI-191 issue resolution will be maintained into the future. This includes maintenance of debris source term considerations and component configurations in the flowpaths that support the recirculation function.

- Implementation of a Sump Protection Program that provides for monitoring of processes and containment conditions important to maintenance of the recirculation function.

- Containment coatings inspection and evaluation procedures were revised to ensure:

  The inspection procedure provides direction that each location of degraded or questionable condition of qualified or non-qualified coatings be promptly entered into the CNP corrective action program.

  Engineering evaluations are performed for each coating discrepancy to establish the extent of condition of the identified failure, and the probable cause for the failure.

Engineering determines the necessary additional evaluations that may be necessary to fully bound the extent of condition of each coating discrepancy, including, as appropriate, performance of expanded visual coatings inspections and performance of pull tests or cross-hatch tests.

Personnel performing initial coating visual inspections or extent-of-condition visual inspections are qualified to the applicable ANSI requirements.

Identified degraded or questionable coatings are remediated prior to plant heat up following a refueling or maintenance outage. This remediation may include recoating the affected area with a qualified coating system, or removal of the degraded or questionable condition coatings to a sound and tightly adhered area.

- An insulation drawing database has been established to ensure that maintenance activities do not change the analysis and modification input assumptions without an appropriate engineering evaluation.

- The inputs and assumptions for debris generation, debris transport, head loss determination (including chemical effects considerations), upstream, and downstream effects analyses and associated testing have been documented in an approved engineering document (subject to the requirements of 10CFR50 Appendix B) to facilitate evaluation of conditions that may be contrary to analysis and modification input assumptions, and to ensure that future changes to the plant can be readily evaluated against these design and licensing basis criteria.

The Plant documents that were revised or developed to support and maintain the required configuration control for maintenance of the inputs and assumptions that support the GSI-191 issue resolution are:

- Maintenance planning and work control procedures and processes were revised to ensure:

Links to design requirements were established to provide the job planners with the tools necessary to correctly plan work activities associated with containment, ECCS, and CTS.

The requirements for performing work in containment while the unit is operating were expanded to include additional requirements associated with protection of the recirculation function including provisions for obtaining engineering evaluations for complex evolutions.

Links to containment inspection requirements are included in job planner's guides to ensure the necessary information is provided in the work packages for implementation in the field.

- Containment access, inspection and surveillance procedures and processes were revised to ensure:

  Procedures for containment access and containment closeout contain the necessary controls to ensure that containment will remain in a configuration that fully supports the inputs and assumptions associated with the resolution of GSI-191.

  Procedures for containment inspections contain the necessary attributes to ensure the inputs and assumptions associated with analyses described previously are maintained. This includes attributes such as coatings, insulation, and latent debris.

- A new procedure was developed to provide guidelines for cleaning of containment during refueling and maintenance outages. This procedure helps ensure the attributes associated with the containment inspection and closeout procedure(s) will be met.

A list of those documents that were revised or developed is provided below.

[plant specific list]

In summary, [plant name] has implemented the necessary programmatic and process controls to ensure the recirculation function will be maintained into the future.