Request for Additional Information
On the NEI Draft of
"PWR CONTAINMENT SUMP EVALUATION METHODOLOGY GUIDELINES"

The NRC staff transmitted a preliminary review dated February 9, 2004, relaying major problems identified in the draft methodology guidance. This request for additional information (RAI) expands on that preliminary review. The following questions and comments are organized into four groups: 1) general requests that apply to the whole document, 2) requests that apply to a particular aspect of the blockage evaluation, 3) a list of guidance areas targeted in this RAI, and 4) detailed questions that apply to a specific location in the text.

1.0 GENERAL REQUESTS

1. Please provide a high-level description of the overall blockage evaluation that describes each of the key components of the evaluation (i.e., break selection, debris generation, debris transport, and head loss), and explains how the results of one component are used by the next. An organizational chart of the evaluation process would be an asset for the reader. Please also explain in the overview whether the various "options" to be encountered in later technical sections are to be viewed as completely interchangeable or as fixed tracks – i.e., does the choice of Option 1 for debris generation dictate the choice of Option 1 for all other aspects of the evaluation? If there are important dependencies between the options of each analysis step, noting them in the overview and then emphasizing them when the various options are presented, would be useful.

2. Please address the level of conservatism that the guidance was intended to support or recommend conservatisms that the utilities should use in their respective evaluations. For example, should each step in the evaluation assume bounding conditions as was assumed in the boiling water reactor (BWR) drywell debris transport study [NUREG/CR-6369], or should analytical assumptions be more realistic? Addressing the issue of appropriate conservatism at the beginning of the guidance, and then aligning subsequent assumptions for each evaluation step with the stated objectives, would be useful. The NEI guidance frequently uses broad assumptions to compensate for missing data and models, and it does not provide suitable justifications that are needed to ensure that engineering judgments are conservatively bounded. Presently, the NEI report contains a mix of assumptions, both over conservative and under conservative. However, the over-conservative assumptions cannot be relied upon to counter the under-conservative assumptions in the overall assessment. In many instances, the phrase "conservatively assumed" was used without any justification to support this position or to clarify the degree of conservatism. For some of these statements, NRC-sponsored research indicates that the associated assumption is *not* conservative. Whenever analyses cannot argue convincingly for a realistic approach, you should consider assuming bounding conservatisms to ensure long-term emergency-core-cooling-system (ECCS) performance.

3. Please address the potential need for additional testing in the NEI guidance. For example, two areas where testing could be beneficial to a utility include the following: (1) when data are lacking for a specific aspect of the evaluation (e.g., insulation-specific destruction pressures), the conservatisms needed to compensate for the lack of data could be so restrictive that the utility could elect to conduct tests to obtain the missing data; and (2) when the plant-specific resolution involves new strainer or screen designs, or significant variations

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on existing designs, these designs need to be tested to ensure their functionality, especially the ability of the design to negate the formation of a thin fibrous debris bed. Please address these potentialities in the guidance.

4. Please explain the basis for applying an extrapolation of existing test data to other untested materials. In the NEI guidance, many parameters -- such as destruction pressures, transport parameters, and head-loss parameters -- were simply assumed with no justification provided. Please provide adequate justification and/or applicable test data, or else consider setting the assumed parameters to a conservative extreme (e.g., an unknown destruction pressure set to the lowest damage pressure known for the most vulnerable insulation type).

5. Why were more analytical tools and methods for the more detailed, complex evaluations, not recommended in the NEI guidance? For example, one area that would benefit from detailed guidance is the systematic estimate of debris generation quantities where these quantities must be evaluated for a relatively large number of break types and locations. Previously, these analyses have used computer codes designed specifically for this purpose -- e.g., the PWR volunteer-plant analyses used a computerized analysis that employed a CAD model of the plant piping systems. The BWR industry also used computerized tools. Also, NUREG/CR-6224 (parametric study of BWR sump blockage) illustrated how this analysis was performed by hand for the BWR volunteer-plant analysis.

6. The NEI should consider summarizing the technology and experience gained during the BWR strainer-blockage resolution. At a minimum, the guidance could describe the advanced strainer designs, how the screen design features work once implemented (for both, passive and active designs), and the testing of those designs. In particular, the guidance could address how the advanced convoluted designs prevented the formation of thin fibrous debris beds. The guidance could also address the advice given in the NRC SER to the BWROG URG, where NRC staff positions were offered on several of the existing deficiencies discussed above.

7. Does the NEI intend to undertake substantial technical review and editing of the rough draft guidance report, to ensure clarity, accuracy, report integration, and correctly cited references? For example, the draft has place holders that need to be completed on the topics of: 1) downstream effects, 2) comparison to regulatory guide requirements, and 3) the emerging concern regarding chemical effects. A number of references were incorrectly cited or missing. Personal communications need to be documented. Please address the overall integration effort intended for consistency in the report (e.g. the treatment of tags & stickers as small pieces in the debris-generation section, but treatment of such debris as sheets that cover the screen in the head-loss section).

8. Could the treatment of coating debris benefit from providing more detailed information, clarification, and integration throughout the report? For example, the likely forms of paint debris is not addressed -- i.e., in some locations, the report treats coating debris as fine particles and in other locations, data for paint chips is presented. The treatment of coating debris as very fine particulate will lead to high transport estimates and associated high head losses. Conversely, the treatment of coating debris as overly large chips could lead to nonconservative transport and head-loss estimates. Please consider providing a realistic size distribution.

9. Why is buoyant debris not assessed more thoroughly? Even though buoyant debris is not likely to cause sump screen blockage in situations where the debris would float well above the sump screen, it should be considered. Situations where it could have a significant impact on long-term cooling include:
    - For a nonsubmerged sump screen, especially in a shallow pool, the buoyant debris that floats to the screen could effectively reduce the screen area available to flow.
    - Buoyant debris can block upper level drains, thereby reducing the sump pool water level.
    - For newly designed sump screens, the buoyant debris could impact the screen in other ways. For example, given the new "tea-cup" design developed for Davis Bessie, where the top of the cup is near the water surface, buoyant debris could potentially be drawn down into the cup and impede the flow of water.

10. Please consider an appendix that contains a data sheet for each type of insulation/fire barrier material, and perhaps for coatings as well. Each data sheet containing product descriptions, manufacturer data, and data determined from relevant strainer/sump-screen testing, would be useful.

11. Please address the use of active strainers.

2.0 REQUESTS CONCERNING PARTICULAR ASPECTS OF THE BLOCKAGE EVALUATION

This section requests further information concerning individual aspects of a sump vulnerability evaluation. The major categories of an evaluation are: 1) the break characteristics, 2) debris generation, 3) blowdown/washdown debris transport, 4) sump-pool debris transport, and 5) the sump-screen head-loss evaluation.

2.1 Break Characteristics

The NEI guidance offers five options for estimating the characteristics of postulated breaks. The first two options are based on strategies previously used to resolve the boiling-water-reactor (BWR) strainer-blockage issue, i.e. either to assume that (1) all of the insulation inside the crane wall is turned into debris or that (2) a pipe is completely severed leading to a spherical damage zone as described in RG 1.82. The third and fourth options employ fracture mechanics and LLB arguments, respectively, to substantially reduce the size of the break and, hence, the postulated quantity of debris. However, since the concepts of using fracture mechanics and LLB in sump screen blockage evaluations have not been accepted by the NRC; should these concepts be included in the NEI guidance? (One concern with reducing the postulated break size is that unusual types of breaks may not be bounded by these assumptions – e.g. Davis Bessie upper head erosion or perhaps seismically-generated breaks.) And although Option 5 bases the assumed break characteristics on a reactor-coolant-pump (RCP) seal loss-of-coolant accident (LOCA), which is certainly one possible type of LOCA; should it be included in the guidance if it is unlikely to represent a conservative break scenario?

Please clarify Section 4.2.2.5, entitled "Other Considerations," in the guidance. Please consider determining the worst-case breaks using a systematic, coupled process evaluating debris generation, debris transport, and sump-screen head-loss for each break to determine which results in the most challenging scenario. For example, consideration of breaks near high concentrations of the more problematic insulations (i.e., CalSil or MinK) and fire barrier material, as opposed to locations with two or more types of insulation as suggested by the guidance, would be useful. The determination of the particulate-to-insulation debris mass ratio (better described as the particulate-to-fiber mass ratio) for each break location depends upon the containment-wide evaluation of the latent/resident debris in addition to the LOCA-generated debris. Unless there is significant particulate insulation debris, the selection of the worst-case break may depend greatly on the amount of resident debris. Due to transport processes like the initial pool fill, breaks located away from the sump screens could actually result in more debris deposited close to the screen than breaks located nearer the screens. The final paragraph in this section regarding the evaluation of probability of failure and the predicted mode of failure could be expanded to include more explanation, evaluation criteria, and examples.

2.2 Debris Generation

2.2.1 Zone-of-Influence

Please provide guidance for accomplishing the mapping of a typical PWR jet to a sphere beyond simply stating the concept of equivalent damage-pressure volumes. The NEI guidance recommends using a spherical-shaped ZOI as was recommended by the BWROG in the URG, repeatedly recommending a spherical radius of 12 times that of the broken pipe diameter (L/D=12). However, this radius was developed for a BWR jet and is not directly applicable to a PWR jet. Please consider that the volume within a particular pressure isobar in a PWR jet could be significantly larger than that for a BWR jet because the primary system pressures are substantially higher in a PWR than in a BWR. In addition, a PWR jet will contain more liquid water to vaporize during depressurization than a BWR jet. Also, limited NRC testing of debris generation in two-phase jets indicated a modest decrease in damage pressure thresholds and an increase in the proportion of smaller, more transportable debris sizes. Therefore, more rigorous mapping guidance aimed at PWRs would be useful.

The BWROG URG mapping model which resulted in the 12 pipe diameters was based on a saturated steam jet at 1070 psig. The BWROG used a computational fluid dynamics (CFD) code to determine pressure isobar volumes within a BWR jet for a number of pipe-break configurations. Please consider using a similar analysis for PWRs if the spherical ZOI method is to be used. If the NEI does not provide this analysis, then please consider having each utility perform the analysis since the model in the BWROG URG does not apply to a PWR. A misapplication of the previous model may underpredict the volume of debris. It is noted in the guidance that an L/D of 12 was used in the parametric evaluation [NUREG/CR-6762], but that study only had the objective of determining whether or not there was a credible concern. A credible concern was demonstrated using a smaller sized sphere than may be appropriate for PWRs; therefore, although its use was valid for that study, please consider that it may not be valid for plant-specific analyses.

The mapping of a PWR jet to an equivalent sphere was not mentioned in the NEI report. Was such mapping performed to justify recommendations regarding the dimension of the sphere? Please also consider that the dimension of the ZOI should be related to the specific insulation products that are impacted. For example, a 12-diameter ZOI implicitly referred to the destruction of unjacketed fiberglass, but this distinction is not carefully explained in the NEI guidance. The uniformity of plant-specific analyses would benefit greatly if this technical topic were addressed thoroughly and accurately in the NEI guidance.

2.2.2 Destruction Pressures

The NEI guidance cites primarily BWROG URG data for insulation destruction pressures, i.e., the threshold pressure where insulation starts to be damaged by the jet. This data was obtained from testing that used an air jet as a surrogate for steam to cause damage to the insulation materials. The jets from postulated PWR breaks would be two-phase; hence, please address the applicability of air-jet-determined destruction pressures to PWR jets. It was noted in NUREG/CR-6762, Vol. 3 that the destruction pressures could be lower for two-phase jets than for air jets based on limited Ontario-Power-Generation (OPG) two-phase test data. If an analytic assessment or additional two-phase testing is not able to validate the applicability of the air jet data for PWR breaks, then please consider assuming conservative reductions of the destruction pressures to ensure long-term ECC. Please correct and clarify the destruction pressures recommended in the NEI guidance (Tables 4.2.5.1-1, 4.2.5.2-1, 4.2.5.3-1, and 4.2.5.6-1). Specific requests pertaining to recommended destruction pressures include:

1. The NEI guidance recommends a destruction pressure of 10 psi for NUKON®, which was previously accepted by the NRC in the staff evaluation of the BWROG URG. Please note that BWROG air jet Test 6-2 in the URG clearly shows substantial damage to a NUKON® blanket with Velcro® band closures at a pressure of 6 psi (i.e., 1.9% fines and small debris and 6.3% large piece debris), demonstrating that NUKON® would be damaged outside the ZOI prescribed by 10 psi. The volume of the ZOI would increase by 30% if the destruction pressure was decreased from 10 to 6 psi. Please consider this concern when estimating the debris size distribution within the 10 psi ZOI, i.e., the acceptance of 10 psi as the destruction pressure likely considered conservative debris generation. In addition, please also consider potential reductions to destruction pressures to offset uncertainties associated with air jet testing (see above).

2. The NEI guidance recommends using the NUKON® destruction pressure for generic fiberglass. Please provide justification for this assumption or simply recommend a conservative, lesser pressure. Note that some insulation types were damaged at a pressure of 4 psig or less.

3. NEI guidance recommends using a destruction pressure of 17 psi for Temp-Mat fiberglass with stainless steel wire retainers (per the URG), but then recommends using the same pressure for all other Temp-Mat configurations and states that this is conservative. Is data available for these other configurations, to verify that 17 psig is conservative? If not, please consider using a substantially lower pressure to ensure conservatism. In addition, please also address the comment section of Table 4.2.5.1-1, which recommends using the NUKON® destruction pressure for Temp-Mat, which conflicts with the earlier guidance.

4. The NEI guidance cites NUREG/CR-6369 for the destruction pressure of Transco fiberglass. Did this document determine any destruction pressures? Was this simply a reference citation error? Please address the destruction pressure of Transco fiberglass.

5. Min-K is listed as miscellaneous fiberglass insulation, whereas NUREG/CR-6762, Vol. 2, lists it as a particulate insulation in the same classification as calcium silicate.

Although these types of insulation do contain small fibers for added strength, it is unclear that these small-size fibers will form a fiber bed similar to those formed by the fiberglass insulations. Min-K, like calcium silicate, can create unusually high head losses across a preexisting fiberglass debris bed. The NEI-recommended destruction pressure for Min-K is <4 psi (like the NRC SER to the URG), but it does not recommend how much less than 4 psi should be considered. Additional guidance would be useful.

6. Does the entry in NEI-guidance Table 4.2.5.2-1, apply to calcium-silicate insulation? If so, then clearly stating so would be helpful. And what destruction pressures are being recommended for calcium silicate? In addition, please address an incorrect reference cited in the guidance related to some OPG test pressures and corresponding recommendations from an NRC reference. The original recommendation of a 20-psi destruction pressure for calcium silicate came from NUREG/CR-6808 (Page 3-18, Footnote 17), not from the NRC SER to the BWROG URG as cited in the draft guidance.

7. The NEI guidance does not include a destruction pressure for mineral wool, asbestos, unibestos, Microtherm, gypsum board, or any of the various foam insulations. This information would be useful.

8. The NEI guidance did not contain a reasonable recommendation for five out of six common fire barrier materials listed in Table 4.2.5.6-1. Except for a single entry (Koolphen) in Table 4.2.5.6-1, please address the bases for assumptions made for the other five entries. If the caveat of "conservatively assumed" is applicable for these entries, then please address the justification for the caveat.

Please consider that testing has clearly shown that destruction pressure depends upon the orientation of the jacket seam. However, the OPG data were not comprehensive enough to provide destruction pressures as a function of seam orientation, and yet, the NEI guidance suggests that credit can be taken for seam orientation (discussed in Section 4.2.5.2) when considering calcium-silicate insulation. For a specific jet and insulation arrangement, an analysis of the seam orientation could be valid, but the plant would then have to maintain these orientations throughout plant operation. However, the seam orientation model is not compatible with the equivalent-sphere ZOI method. The spherical ZOI functionally homogenizes all of the break orientations and jet reflections associated with unspecified obstructions. Hence, jacket-seam orientations can no longer be correlated with jet orientations. Please consider addressing this in the guidance.

2.2.3 Debris-Size Distributions

The degree of damage to insulation debris is a necessary input to the debris transport analysis and is usually presented as a size distribution for each type of debris. Please consider correcting or improving specific problems identified in the NEI guidance for estimating the size distributions of LOCA-generated debris. They are as follows:

1. The NEI guidance for a suitable debris-size distribution for NUKON®, which was recommended as a surrogate for several other types of insulations as well, simply referenced NUREG/CR-6772. The NUKON® debris described in NUREG/CR-6772 was created by passing NUKON® insulation through a leaf shredder to create a reasonable substitute debris type for the purposes of those tests. No size distribution was

provided. Please consider providing guidance for a size distribution for NUKON® which includes the fraction of the insulation that is destroyed into very fine and highly transportable debris, the fraction of small-piece debris (similar to the debris produced by the leaf shredder), and the fraction of larger size debris (illustrated in the NEI Table 4.3.3.6-1). For example, it was found in the DDTS experiments [NUREG/CR-6369] that 15 to 25% of an insulation blanket that was completely destroyed by the air jet was degraded into debris so fine that it could not be collected by hand. Much of this fine debris was small enough to pass through a fine-mesh collection screen and would almost entirely transport in a PWR to the sump pool where it would remain suspended until it was filtered from the flow at the sump screen. Accounting for this very fine debris fraction in the debris generation and transport analyses would be useful. Other valuable sources of data for debris-size distributions are the descriptions of damage found in the BWROG URG for their air-jet debris-generation tests.

2. The NEI guidance recommends assuming the debris-size distribution of NUKON® for several other types of insulation including Temp-Mat, mineral wool, generic fiberglass, and most of the fire barrier materials. No physical foundation is provided for this recommendation. Please consider conservatively skewing the size distribution towards the smaller and more transportable sizes to compensate for the lack of debris-size data, or conducting appropriate testing to obtain the missing information.

3. For Min-K insulation, the NEI guidance simply noted an observation made from a SEM photo. Providing a size-distribution recommendation for Min-K would be useful. For calcium silicate, OPG data is provided stating that 75% of the debris will be fines. Noting that calcium-silicate debris has a strong tendency to further degrade into fine particulate, especially in hot water, it could be assumed that all of the calcium-silicate debris is in the fine size category and that nearly 100% transport to the sump screens will occur if the containment sprays activate. Please consider that it is likely that Min-K would behave in a manner similar to calcium silicate. If applicable data is lacking, then please consider assuming that Min-K is also reduced completely to a fine and highly-transportable debris size.

4. For RMI insulation debris, the NEI guidance recommends a size distribution from Ref. 7-32 without including the distribution in the guidance. Does Ref 7-32 (an industry report for NUKON®) include a size distribution for RMI? Was the intended reference the NRC-sponsored Siemens test summarized in NUREG/CR-6808 (Figure 3-7, Page 3-15)? If this is the case, then the recommended size distribution is very conservative for the overall ZOI because the RMI cassette in the Siemens test was placed directly over the break jet to ensure complete destruction. In addition, please consider that this data applies specifically to DPSC Mirror SS RMI cassettes and may not be applicable to other types or manufactures of stainless-steel RMI.

5. Debris-size distributions can only be obtained from applicable experimental data, i.e., debris-size distributions observed for specific insulations damaged at specific jet pressures. Insulation near the break is typically totally destroyed resulting in fine or small debris, whereas debris nearer the threshold pressure may only suffer minor damage resulting in larger debris pieces. Please include a discussion in the NEI guidance addressing the conversion of type-specific and pressure-specific damage data to a spherical ZOI. Such a method is outlined in Section 3.3.3, of NUREG/CR-6808, and

may be useful. Note that directly applicable data exists for only a few types of insulation.

6. Over time, various studies have described the size distributions of debris differently. NUKON debris has been categorized in as many as 7 classes and as few as 2 classes depending upon the analytical treatment. The NEI guidance currently presents multiple classification systems, but to improve understanding and consistency, please consider settling on a classification system(s) and relating all further guidance to that description. A system based on debris-transport characteristics would be effective -- e.g., NEI Table 4.3.3.6-1 for fibrous debris.

2.2.4 Latent Debris

The NEI guidance states that samples collected during insulation walkdowns resulted in no more than 3 lbs of debris per 10,000 ft^2 of horizontal surface area and that a generic upper bound for the latent debris is 150 lbs. How and where was this debris collected? Please provide detailed information regarding these debris samples to allow an evaluation of the quality of the data. Do horizontal floor-surface estimates consider latent debris in more remote places such as cable trays and on and around equipment? Based on past descriptions of latent debris and ongoing research, is it possible that 150 lbs represents a typical quantity of latent debris rather than an upper bound? The debris characterization tests ongoing at Los Alamos National Laboratory (LANL) may provide additional insights on this matter. The guidance cites the foreign material exclusion (FME) program as justification for limited latent debris; therefore, please provide guidance that validates the effectiveness of this program for a recent period of operation. Consider that

GL-98-04 compiled information from plant inspection reports as recent as 1996 that clearly showed substantial quantities of debris found during maintenance outages -- e.g., five 55-gallon drums of sludge removed from the Haddam Neck ECCS sump [LER 96-014-00] along with an assortment of miscellaneous debris. If the FME program is used to limit latent debris in sump-screen-blockage analyses, recent inspection reports ensuring the effectiveness of the program would be useful. Please consider additional evaluation on this issue.

2.2.5 Generation of Debris by Containment Sprays

The NEI guidance describes conditions whereby debris could be generated by the sprays; however, little data is provided regarding erosion rates for exposed insulation or failure rates for nonqualified coatings. Please address these erosion and failure issues in the guidance. Some erosion rate data was reported in NUREG/CR-6369, which may be useful. A model is offered there for the erosion of insulation where the jacketing does not overlap, but the basis of this model is not supplied or validated. Please also more thoroughly address the erosion of larger debris that does not transport to the sump pool, but is also subject to erosion by the sprays. Because spray operation may be of relatively short duration, degradation rates may be useful to estimate the total amount of fine transportable material generated during this time.

2.3 Blowdown/Washdown Debris Transport

1. The NEI guidance refers to NUREG/CR-6762, Vol. 4, as the basis for transport logic charts. Please note that the charts developed in that report, including the assigned distributions, applied to the generic parametric evaluation and are not plant-specific. The NEI guidance is

so simplistic (i.e., Figure 4.3.3.2-1) that it does not illustrate much of the complexity associated with this transport analysis, and it does not show the possible variations in the analysis that would be associated with different plant containment designs. Each step in the simplified charts represents a fairly difficult analysis for which guidance is not provided. Please address how each plant is expected to apply this chart, considering that a realistic debris transport analysis is much more complex than the NEI guidance illustrates.

2. Airborne/washdown transport of fine debris (e.g., individual fibers) is likely to be nearly complete when the containment sprays operate. Although some portion of the fine fibers will be trapped at various locations, nontransport can only be justified when airborne fibers are deposited at some location not impacted by sprays. Such locations represent only a small portion of the containment surface area. Please consider verification of the assumption of nearly-complete transport of fines using an NEI calculation. A time-saving consensus recommendation could thereby be made to emphasize nearly-complete transport. Alternatively, NEI may consider emphasizing those aspects of the analysis that were found amenable to refinement to help prioritize licensee analysis efforts.

3. A statement is made (Page 78) that if the containment sprays terminate, the washdown of debris from the upper levels of containment is also terminated. However, the present ability to predict washdown debris transport is not sufficiently developed to support a time-dependent debris-transport estimate. Hence, if the sprays operate for any period of time, please consider that the washdown transport fraction is complete, unless a more thorough physical model can be presented to support the contrary. Please note that existing containment-water inventory calculations do, however, provide valuable insights into the time and location dependent drainage paths that introduce debris to the sump pool.

4. Generic retention fractions are offered in the NEI guidance for the washdown transport analysis. Please justify each of these fractions, not only for review purposes, but also so that plant personnel can evaluate under what conditions they may wish to deviate from these numbers. Also, please note that the fractions offered in the draft guidance are not comprehensive and that retention fractions can be plant-specific.

5. Please consider noting in the guidance, that NUREG/CR-6369 has information applicable to the erosion of fibrous debris by falling water. This may be useful.

6. Please consider noting in the guidance, that debris trapped in the upper reaches of the containment -- e.g., debris blockage of a refueling-pool drain -- can also retard water drainage and subsequently affect the sump-pool water level.

2.4 Sump-Pool Debris Transport

2.4.1 Initial Debris Distribution

The NEI guidance recommends assuming that the break-flows uniformly distribute debris about the floor of the compartment where the postulated break occurs and that, if the containment design is open, then the debris may be distributed uniformly about the entire containment floor. For additional guidance on introducing the debris to the sump pool, please consider that, in reality, the introduction of debris is both plant-specific and transport process-specific. For example, in the volunteer-plant analysis, most of the debris deposition at the sump level during blowdown transport occurred in the steam generator compartment where the break occurred, which concurs with the NEI guidance; however, in a more open containment design, uniform deposition across the entire containment floor is not necessarily the correct assumption. Rather, please consider that each plant could assess the proper distribution pattern to assume for initial debris deposition. This distribution can have a significant impact on the debris transport results depending on the relative location of the sump. Further, it can be estimated by examining the steam expansion flow paths around the break in combination with existing debris-generation test data describing the recovery locations of various debris-fragment sizes. Also, a large portion of the debris, if not most of the small-size and fine debris, would be transported throughout the containment building and reintroduced to the pool, along the containment-spray drainage pathways.

2.4.2 Pool Formation Debris Transport

Please consider providing guidance regarding the pool formation water flows and the concurrent debris transport. The guidance document simply states that engineering judgment is to be used to determine the movement of debris about the containment floor. Analyses performed by LANL have demonstrated the pool formation process, and experiments have shown the effectiveness of the initial sheeting flow at moving debris. Please address that sheeting flow could move the debris preferentially towards the sump screens, away from the screens, or even into dead-ended spaces. Please also note that these processes also depend on the location and size of the break. Because inspection could lead to incorrect and nonconservative debris transport results, it would be useful if engineering judgments were supported by meaningful analyses such as CFD pool-formation calculations or open-channel drainage-flow calculations. The obvious conservative position would be to assume that all initially-transported debris is located adjacent to the recirculation sump screens, but significant reductions in transport may be found by appropriate credits for sequestration in dead-end sump areas that are not affected by spray-drainage cascades. In fact, some licensees could consider diversion of debris during the pool-fill phase as a cost effective mitigation strategy that takes advantage of existing containment-floor geometries.

2.4.3 Distribution of Debris Washed Into the Pool

In the NEI guidance, please address how debris washed down from the upper containment is to be introduced into the sump pool. Please include proper distributions in estimating debris transport within the pool. For example, debris trapped within the compartment containing the break would wash to the bottom of that compartment, but consideration that the debris distributed to regions outside of the break compartment would enter the pool at as many locations as the spray drainage enters the pool, would be useful. Another example is, assuming distribution of the debris in proportion with the spray drainage -- e.g., if 10% of the drainage enters the pool from a given stairway, then 10% of the debris washed down from the upper containment also enters the pool at that location. Alternatively, the guidance could recommend that all debris washed down from upper containment be considered transportable because of degradation in the turbulent splash zone, thereby obviating the need for location-specific distributions. Please consider these approaches to addressing this issue.

2.4.4 Debris Transport Estimates in the Pool

Please provide a degree of fidelity for pool transport modeling, perhaps above any other single aspect of an ECCS vulnerability assessment, in the proper context with respect to assumptions made in the other phases of the accident analysis. For example, please consider the focus in the guidance, on the details of computing water-flow velocities that induce debris transport. NRC-sponsored research has systematically examined all of the phenomena associated with the realistic accident sequence, and the expectation for such research tends to be the eventual development of a predictive, deterministic approach for modeling the entire progression from debris generation to ultimate head loss. Consider that this level of detail may be warranted in some circumstances, but in others, it will not be.

In the focus of the pool transport analysis, please consider reflecting the type and size of debris transported, specifically considering debris that is not so likely to transport to the screen. Hence, the results of the blowdown/washdown debris transport and the assumptions associated with that analysis impact the focus of the debris transport analysis. The aspects of debris transport that will have the most significant effect on reducing the transport fractions will depend upon both the characteristics of the debris and the conditions and geometry of the pool. For example, in a slowly-flowing pool where substantial debris-curbing surrounds the recirculation sump, little large debris would be expected to transport to the screen. In a situation where substantial small debris enters the pool and subsequently settles to the pool floor and the transport conditions are marginal, then a larger analytical effort could well payoff in a reduced transport estimate. Suspended debris, such as individual fibers will almost certainly transport to the screen over long term operation. Illustrated practical tradeoffs throughout the guidance would help licensees prioritize their analytic investments as well as reinforce the integration and interaction of assumptions throughout the assessment.

Specific requests on this section of the NEI guidance include the following:

1. NEI guidance regarding the CFD approach appears to focus on floor-level debris transport -- i.e., tumbling and sliding. Again, please consider that the fine suspended debris would all transport to the screens. Please consider using velocity contours to estimate floor fractions where the flow velocities are less than a particular transport velocity. This approach is then very dependent upon where the debris is introduced to the pool (see above discussion). Although the guidance appears to recommend a uniform initial debris distribution, please consider that high water velocities during pool formation would skew debris into geometry-specific patterns. Also, consider that washdown debris would enter with the drainage flows, hence, the debris may enter the pool in proportion to the volumetric flow of the drainage paths. Please also address consideration for debris initially introduced at locations of higher velocity that subsequently move into locations of lower velocity, and the finer pool details such as eddies and turbulence, in the guidance. Regarding code convergence criteria in the NEI guidance, please consider referring the user to specific software recommendations because implementations of these types of criteria can be code-specific. These improvements, introduced conservatisms, and validation by comparisons with experimental transport results could be useful in the NEI pool-transport guidance. Another, more refined approach than the floor-fraction percentages might be to consider debris transport along flow streamlines that exceed the incipient transport velocities.

2. The NEI guidance presents the network method for open channel flow as a method of determining flow velocities. The guidance also notes substantial limitations associated with this method including its inability to predict turbulence intensities, flow separations and eddies, three-dimensional velocity profiles, pool formation transients, and the

difficulties of simulating complexities such as multiple flow entry locations associated with realistic containment-spray drainage. Appendix C provides a comparison between bulk-flow velocities estimated by the network method and by CFD calculations. (Note that the title to the appendix claims a comparison of transport factors but no transport factors were included). The bulk velocities did compare reasonably well; however, please address the validity of the method used (for example, by referring to it's previous use or validation, in an NRC-accepted application). Please further explain the stated need to check for super critical flow conditions (analogous to sonic flow), which seems out of place in this context. And please address the basis for claims regarding conservatism of results -- i.e., it would be helpful if the claims could be supported either by comparisons to experiment or example calculations.

3. Please consider providing more supportive arguments in the NEI guidance regarding the entrapment of debris behind curbs to justify the argument for permanent debris retention. Please consider addressing the interaction of debris loading behind the curb on subsequent debris accumulation. The debris lift velocities measured during the NRC-sponsored separate effects debris transport tests [NUREG/CR-6772] involved a relatively 'clean curb' -- i.e., the tests introduced only small quantities of debris so that each piece encountered a relatively unencumbered curb. Please address the situation where larger quantities of debris could accumulate behind a curb, thereby creating a ramp. Consider that the resulting velocity needed to lift additional debris over the curb could be substantially reduced from that measured for a clean curb.

4. The NEI guidance states that debris located in dead-ended compartments will not transport, which is more applicable to debris already settled on the floor in dead-end compartments. However, please consider addressing how suspended debris can transport in the long-term from such a compartment if even a small amount of water flow occurs.

5. Please consider assessing the potential for water-level drop at the recirculation sump screen, if screens in the containment-water drain paths can accumulate enough debris to significantly retard flow. Please also address how lower water levels negatively affect sump-screen failure thresholds.

6. NEI guidance for CFD transport analysis (Page 87) suggests using the minimum bulk transport velocity as a criterion for debris motion. NEI guidance for the network-method transport analysis (Page 90) suggests using the incipient transport velocity. Please consider recommending the same motion-velocity criterion for both methods, unless specific reasons can be provided otherwise. Consider that, if an occasional piece of debris can move, then bulk transport could occur over an extended period of time. Also, pulsation from flow turbulence can facilitate motion of a piece of debris that would not move ordinarily in nonturbulent conditions. Please consider using the lowest incipient velocities measured for specific types and sizes of debris under relevant flow conditions to describe debris motion. Also consider applying this to tumbling and lift velocities.

7. The NEI guidance contains a table of transport velocities, Table 4.4.3.4.2.5-1, for which the following requests apply. As explained in item "f." below, it is requested that the column labeled "bulk transport velocities" be deleted, thereby presenting only one set of velocity thresholds for debris transport on the floor. Please consider including "insulation density" in the table, which could be useful since there appears to be a

possible correlation between incipient transport velocities and material density. Also, for settling velocities, consider citing the range and recommending use of the lower values to ensure conservative transport, instead of citing averages. Please consider the following additional requests concerning this table.

a. NUKON®. The recommended curb-lift velocities of 0.22 and 0.25 ft/sec for 2- and 6-in curbs, respectively, were based on the minimum test velocities at which debris was observed to lift (test configurations B and C, respectively in Table C.3 of NUREG/CR-6772). Please consider reducing these velocities slightly to 0.19 and 0.22 ft/sec, respectively, to account for test variability that obscures the transition between debris lift and no debris lift. Also, please address how the comment for the NUKON entry refers to Table 4-8 of NUREG/CR-6224, but that NUREG/CR-6224 does not have a Table 4-8.

b. Generic Fiberglass. Please provide additional qualification for the use of NUKON® data for generic fiberglass needs. For examle, please consider that if the generic fiberglass is heavier than or as heavy as NUKON®, then the NUKON® transport velocities are adequate. But, transport velocities for a lighter variety of generic fiberglass could be lower than those for NUKON®. Consideration for these dependencies could be useful.

c. Temp-Mat. What is the pertinence of the comment stating that Temp-Mat has a "lower damage pressure" than that for NUKON, in the transport-velocity table? And, how is the reference which cites the debris-generation section of NUREG/CR-6808 (*Section 3.2.1.2*) relevant to this *table?*

d. High-Density Fiberglass. Please consider that this type of fiberglass be described by its various material properties including density to ensure that the higher transport velocities recommended for high-density fiber are not used for lighter fiberglass products other than those actually tested. Also consider that the preparation of the fiberglass shreds tested in NUREG/CR-2982, Figure 2.12, tended to create more standardized pieces of debris than have been created recently using a leaf shredder or those that would be created by a LOCA. Hence, the adequacy of representing the finer pieces of LOCA-generated debris (and perhaps less dense materials) using the NUREG/CR-2982 transport velocities, should be considered.

e. Thermo Wrap. Please consider either providing the information for Category 'c' (i.e., the incipient transport velocity, the curb lift velocity, and a description of the tested debris), or delete the designation of Category 'c' until more complete information can be provided. Also, why are the cited documents not included in the list of references? Has the referenced data been made available to the NRC ?

f. Mineral Wool. Again, please consider providing more descriptive information (e.g., density and shred sizes). Please expand in the report on the comment regarding the floatation of mineral wool. For example, if it floats, then transport to the sump would be complete unless dead-end entrapment can be defended. However, the floatation data is not comprehensive because the hottest temperature tested was initially only 120°F and that temperature was not sustained. Hence, mineral wool could readily float to the sump screen first and then subsequently sink later during the accident sequence. Note that test data for mineral wool is very limited in the open literature. Further discussion on the impact floatation would be useful.

g. Asbestos and Unibestos. NUREG/CR-6762, Vol. 2, lists asbestos and unibestos as particulate insulations. Therefore, why is NUKON data recommended as a surrogate for asbestos and univestos, when their transport behaviors are likely to be more similar to those of calcium silicate than those of NUKON? Please consider assessing the physical properties of these materials in comparison with materials of known transport properties. Then, consider adding an extra factor of conservatism to compensate for the complete lack of data.

h. Calcium Silicate. Because a large fraction of the LOCA-generated calcium-silicate debris would already be in the dust form (OPG data), and because the remaining damaged pieces tend to disintegrate into silt when transported in hot water, especially when subjected to turbulence, please consider assuming that all of the damaged calcium silicate within the sump pool transports to the sump screen. Please consider and address that claims of limited disintegration of damaged Cal-Sil at higher elevations because of limited-duration containment sprays would require empirical erosion rates.

i. Stainless-Steel RMI. Please consider changing the lift velocity over a 6-in curb from ">1.0 ft/sec" to "1.0 ft/sec" so that the guidance is more definitive. What is the intended context of the discussion regarding "approximately 2/3 of RMI remaining suspended"? Why is it included here? Please consider that this comment addresses the suspension of debris by turbulence; a topic that could be usefully addressed in a separate section that explains how to assess the effect of turbulence on all types of debris.

j. Aluminum RMI. Why is stainless steel-RMI data applied to aluminum-RMI, when the aluminum is lighter and will transport and lift at lower velocities than stainless steel for a given size of fragment?

k. Fire Barrier 3m Interam & Fiberglass Blanket. Please consider sustantiating the assumption that NUKON data can be used, by comparing the material construction, constituents, and densities to formulate a basis for the assumption. Please note that, if either of these materials is less dense than NUKON, then that material could transport at lower velocities than NUKON. Is 3m Interam fibrous?

l. Koolphen. Why is it assumed that NUKON data can be used as a surrogate, when this material (closed-cell phenolic) is not similar to NUKON?

m. Min-K. This material is a particulate insulation type. So, if its transport behavior is likely to be more similar to that of calcium silicate than to NUKON, then why is NUKON data recommended as a surrogate? Similar to the case of calcium silicate, please consider that 100% transport of damaged Min-K in the pool should be assumed.

n. Lead Wool. Why does the guidance assume that this material will settle and not transport, when its density is not much higher than that of high-density fiberglass insulation, which was assumed to transport? Please consider that all materials will transport at some velocity, so if lead wool is present in containment, its potential transport cannot be dismissed. Please consider determining its properties by testing or by comparison with other well-characterized materials.

o. Dust/Dirt. The NEI suggests using calcium silicate data for dust/dirt. The above review request suggests 100% transport for damaged calcium silicate because of its tendency to disintegrate into fine silt-like particles. Please consider that the transport of dust/dirt will depend on particle size. For example, finer particles and fiber will remain suspended and transport completely, and heavier particles could settle and remain in place. The conservative assumption of 100% transport could be useful as an option, but more refined guidance might be based on NRC-sponsored research into latent debris characterization.

p. Coatings. The NEI guidance for coatings is based on the paint sample artificially created for UNM transport tests (NUREG/CR-6772). Please consider expanding the sample, covering a spectrum of sizes, including fine pigment-base particulates, in order for the guidance to consider more than one classification of coating debris.

2.4.5 Debris Disintegration

What is the basis for the NEI guidance on debris disintegration (Section 4.4.4.3, Page 91)? Please consider that at least two test series have shown that fibrous debris disintegrates in a turbulent pool, but the data are currently inadequate to correlate the rate of disintegration with the degree of turbulence. Neither is it known whether other parameters such as pool chemistry would affect the rate of disintegration or whether there is an effective threshold for the level of turbulence that can induce disintegration.

a. The NEI suggests using engineering judgment to estimate the rate of disintegration using the calculated fluid velocities. It states "If the calculated fluid velocity is less than the incipient transport velocity, fibrous debris is not likely to be subject to disintegration and it may be neglected." What is the basis for this position? Please address turbulence in some detail, and consider that based on observations during the integrated debris transport tests [NUREG/CR-6773], it is possible that debris could remain trapped in eddies at the boundaries of moving water zones and continue to disintegrate at a slow rate. Please also consider that, even a slow rate of disintegration can become important during a long-term cooling scenario. Note that the integrated debris transport tests were limited to a few hours.
b. Please consider disintegration for all debris types where disintegration is possible. For example, some materials such as RMI will not disintegrate in the pool, but for some materials such as calcium silicate, the disintegration may be complete.
c. Without adequate data, please consider basing the rate of disintegration on a conservative physical rationale.

2.5 Sump-Screen Head-Loss Evaluation

The NEI guidance proposes using the NUREG/CR-6224 correlation for predicting head loss across fibrous debris beds, but please consider improving some of the guidance regarding debris-specific input parameters. Please note that the proposed correlation is empirically-based, meaning that several coefficients are used to best fit the correlation to observed data. Another way to look at the correlation is that it provides a means of extrapolating from known test data to postulated plant conditions that are not too dissimilar from the known test conditions. The following requests apply to the NEI guidance:

1. The NEI guidance states that the NUREG/CR-6224 correlation has been extensively validated (Page 110). How has it been validated for the insulations and particulates expected in PWR scenarios? Although the form of the correlation is thought to be robust for these applications, please consider citing (in the NEI guidance) the studies that have provided validations for relevant materials. Please also consider and address that, for other materials not previously tested, validation studies should be performed to ensure that appropriate input parameters are used in the correlation.

2. The NEI document provides guidance for estimating the specific surface area parameter (ft^2/ft^3) for the correlation by examining the characteristic diameters of particles and fibers. This guidance was adapted from NUREG/CR-6371, written in 1996. However, please consider and address how experience gained since then, has demonstrated that estimating the specific surface area in this manner can underestimate the specific surface area, and hence, the predicted head loss. Then please consider the alternative approach of applying the correlation iteratively to applicable test data -- i.e., by adjusting the specific surface area until the correlation correctly predicts the head loss observed under conditions where all other parameters are reasonably well-controlled. Also, please note the following detailed requests:
   a. Please consider and address how attempts to estimate the specific surface area by the geometric method of a dirt sample generated for head-loss testing at UNM, underestimated the specific surface area determined through the application of the correlation to test data by a factor of 4.
   b. Please consider and address that, if a specific surface area is estimated for the BWR-URG data for a typical size distribution of corrosion products (see NEI table on Page 5 of Appendix D), the estimated surface area is a factor of 3.8 smaller than the area of 183,000/ft recommended in NUREG/CR-6224. Is the data in the NEI table incorrectly labeled as "% by weight"? Please not that, in the URG, these same percentages were in "% by the number of particles."
   c. Please consider and address the simple geometric equation used for estimating the specific surface area of a particle assumes perfect spheres. Please note that readily available literature has more advanced formulas that include such terms as the shape factor.
   d. In the iterative comparison of the NUREG/CR-6224 correlation to data, uncertainties and variabilities are subsumed into the specific surface area estimate as the area is adjusted to fit well with the observed data. So, in a sense, the surface area is a bulk parameter that accounts for both deficiencies in the form of the equation and variability in the observed data. Please consider that independent estimates of the surface area (like geometric analysis or direct measurement of surface pores) do not provide the same perspective as a best-fit parameter. In this light, please consider and address how they could be interpreted and applied in the guidance.

3. The NEI guidance offers an equation for blending specific surface areas for a variety of materials that may coinhabit the debris bed. The guidance references NUREG/CR-6371, however, please address why the presented equation is different from that provided in NUREG/CR-6371. For example, specific surface areas in the NEI guidance are based on the square of the individual areas, whereas in NUREG/CR-6371, the areas are combined using linear powers of the individual areas. Please discuss the impact of this difference, and justify the NEI equation through the application of the correlation to debris beds consisting of multiple types of debris. Also, please consider and address that while the NEI guidance provides an equation to blend the specific surface areas, it fails to provide guidance for blending various densities for a mixture of debris, such as multiple types of particulates.

4. The NEI guidance uses a density of 65 lb/ft^3 for a generic debris type called "sludge" regardless of the actual debris material. Please consider identifying this density for iron-

oxide sediment, but otherwise, providing debris-specific densities in analyses. Please consider that if a generic sludge density is desired, some assessment of the head-loss correlation be offered to assure that the recommendation conservatively bounds all reasonable particulate types. For example, for dirt or concrete dust, where the particle density is perhaps one-half that of iron oxide, the sludge density will be much less than 65 lb/ft^3. The porosity of a granular particulate bed depends on the ratio of the sludge density to the particle density, hence, it is the assumed ratio of these two densities that is the key issue. [The term "sludge" was applied to the correlation during the BWR resolution because iron-oxide corrosion products represented the dominant particulate. A better name might be the "mud density" or the "granular density". In effect, the sludge density determines the packing limit for a mixed bed undergoing compression with a high particulate-to-fiber ratio.] Please consider that sludge density is another parameter that could be derived from experimental observations by applying the NUREG/CR-6224 head-loss correlation when multiple types of particulates co-inhabit the bed.

5. The NEI guidance recommends a condition of solidarity based on the sludge density as a limit to debris bed compression (Page 112). The solidarity of a debris bed depends on the density of the fibers as well as on the density of the particulates, but the sludge density typically is based on the particulate density alone. Please provide an equation in the guidance that relates the bed solidarity to the sludge density. NUREG/CR-6371 and the BLOCKAGE code documentation have provided this relationship, which may be useful..

6. The NEI guidance for fiber-bed compression includes an additional coefficient (Page 112) that is not found in NRC-published reports. The new coefficient effectively modifies the correlation's associated compression equation. It is recognized that the compression equation was validated for NUKON but that the coefficient (and the exponent) could be modified for other types of fibers. However, NEI did not provide guidance for selecting values of K other than 1. Please consider and address the need for deduction of appropriate values from test data. Please consider that application of this new coefficient can lead to erroneous head-loss predictions without complete and appropriate guidance.

7. The NEI guidance correctly recommends using a conservatively-low water temperature when estimating head loss because of the higher water viscosity. However, are safety analyses performed to determine the conservative peak water temperature, suitable for predicting the conservatively-low water temperature? For example, it is conservative to neglect some heat-transport processes and non-safety-related equipment when estimating a conservatively high temperature. But please consider the need for including these same processes and equipment in the low temperature predictions, so that the estimate of water temperature is compatible with a conservative head-loss prediction.

8. The NEI head-loss guidance suggests that sheet types of debris (e.g., plastic sheeting and mats) be treated as reducing the effective screen area (Page 99), but the debris-generation guidance (Page 55) suggests that stickers and tape are destroyed into small pieces (presumably to the size of particulates). Please clarify in the guidance, what type and size of debris should be assumed. Perhaps it would be useful for both methods to be evaluated and the one that predicts the higher head loss, be reported. Please consider that, if there is already plenty of particulate in containment, then treating sheet debris as

reducing the effective screen area is probably the more conservative approach.

9. In light of the above comments regarding the proper determination of specific surface areas, please consider that the NEI recommendation to treat unqualified coatings as disintegrating to pigment-base particulates could lead to conservative but unacceptably high head-loss estimates. This is because the appropriate specific surface area for 10-micron particles may be as much as four times higher than NEI-anticipated areas that are based on the geometric diameter alone. Please consider providing a more realistic treatment for plants that cannot tolerate such over conservatism, but note that applicable data are not available.

10. The NEI head-loss guidance suggests (Page 109) that time-dependent head-loss predictions can be performed in conjunction with time-dependent pool temperature calculations. However, debris transport cannot be modeled in a deterministic manner that reliably predicts time-dependent mobility. For this reason, please address treatment and validation of the quantity of debris assumed in the bed if a partial portion of transportable debris is presumed. Please consider and address the approach of conservatively presuming that all debris capable of transport to the screen is placed on the screen initially. Please also consider the benefit of time-dependent calculations of water level that directly controls the amount of static head available for water flow across a debris bed.

11. Please expand on the formation of thin-beds and its effect. Please address the following specific considerations.
    a. In the scoping evaluation mentioned in the guidance, please address the possibility of establishing a thin bed across the existing screen, as was done in the parametric evaluation. Please expand this scoping evaluation to include (1) estimating the quantity of fiber required to create a ~1/8-in thick debris bed across the screen, (2) estimating how much particulate it would take to establish a head loss sufficient to exceed the NPSH margin, and (3) comparing these quantities to the anticipated quantities of debris in containment.
    b. Please consider and address that the 1/8-in thickness is an approximate number that could depend upon the type of fibers. For example, if the particulate is calcium silicate and the screen mesh is relatively fine, it does not take 1/8-in of fiber to filter calcium silicate from the flow.
    c. In the guidance, please consider providing an example thin-bed calculation using a comparison to test data.
    d. In the guidance, please include a discussion of operationally-created thin-beds (e.g., Perry and Limerick).

12. In the NEI guidance, please develop a section on strainer design that discusses the new technology that was used to resolve the BWR strainer clogging issue. For example, please consider discussing in-detail the reasons why the stacked-disk strainers were successful at defeating thin-bed formation, accommodating large debris volumes and permitting adequate flow. Specifically, the convoluted design forced the approaching flow to sweep parallel across the internal faces of the disks so that debris tended to be pushed along the surface towards the interior debris traps near the center. This passive flow action, a simple result of flow-resistance gradients across the screen, encourages

efficient packing of debris without inducing extreme pressures that lead to compaction and high head loss. This concept, in addition to the high surface area per unit volume, are the foundations of advanced strainer design, which could be useful in the PWR sump-screen clogging resolution as well.

13. In the NEI guidance, please consider addressing debris beds that contain very little fiber. For example, it is possible to have a debris bed consisting of only calcium silicate, if the screen has a fine enough mesh. In such situations, a granular-bed head-loss correlation may be more applicable than the NUREG/CR-6224 correlation. Such recommendations could be useful.

14. The NEI guidance discusses a method of iteratively solving the NUREG/CR-6224 correlation including example solutions. Please consider also mentioning the NRC-sponsored BLOCKAGE code, and presenting the pros and cons associated with its application to PWR sump screens. BLOCKAGE implements the head-loss correlations and can be used to perform screen vulnerability calculations and manual iterations to confirm the appropriate choice of material parameters when data are available for comparison.

15. In the NEI guidance for RMI debris beds, please consider presenting a complete set of K_t data rather than a single value. The value presented would pertain to stainless steel (mid-size range). Please note that NUREG/CR-6808 contains a more complete set of data that includes values appropriate for aluminum RMI as well.

16. The NEI guidance discusses the application of the NUREG/CR-6224, correlation to microporous and fiber debris combinations. It states that the correlation is good up to a particulate-to-fiber mass ratio of 20%. Please consider replacing this guidance with recommendations based on the recent NRC calcium-silicate test report that provides the specific surface area for the calcium silicate product that was tested. Please note that parameters for Min-K are likely to be similar to those for calcium silicate, and perhaps can be used as a surrogate for Min-K if a conservative margin is applied in conjunction with an appropriate rationale.

17. Please add the specific surface area and the debris sludge (granular) density for each type of material in Table 4.5.2.4-1. Is the 40-micron mean particle size reported for calcium silicate too large?

18. Please consider adding a summary of available test data (e.g., provided in URG) that includes NRC-, industry-, and internationally-sponsored tests, and lists the types of materials tested, describes how the tests were executed, and perhaps provides the range of test conditions. This could be useful.

3.0 GUIDANCE TOPICS TARGETED FOR ADDITIONAL INFORMATION

The following topics represent areas where either the current NEI guidance needs to be supplemented or a modest effort could substantially improve the usability of the document.

1. Overall evaluation flow chart
2. Establish level of conservatism expectations

3. Jet-to-sphere mapping
4. Establish destruction pressure extrapolation rationale
5. Complete table of destruction pressures
6. Computerized analysis tools (e.g., CASINOVA, BLOCKAGE)
7. Conservative ZOI debris-size distributions
8. Latent debris characterization and quantities
9. Characterization of coating debris
10. Generalize airborne/washdown guidance for PWRs
11. Spatial debris distribution entering pool
12. Establish transport parameter extrapolation rationale
13. Pool debris-transport model during pool formation
14. Pool debris-transport model in established pool
15. Pool debris-disintegration model
16. Apply NUREG/CR-6224 to test data to deduce suitable input parameters for application of correlation
17. Establish head-loss parameter extrapolation rationale
18. Develop guidance for buoyant debris
19. Prepare computerized comprehensive solution of NUREG/CR-6224 correlation (e.g., PWR Version of BLOCKAGE)
20. Description and treatment of potential chemical effects

4.0 DETAILED TEXT-SPECIFIC QUESTIONS

- Please consider adding a list of abbreviations.
- Page 9, Section 1.1, third paragraph. Please explain why the intention is not to replace the plant licensing or design bases, when in fact the design-basis may be replaced.
- Page 18, first paragraph. Please update the reference to a draft RG 1.82 Revision 3, to the final version which was issued November 2003.
- Page 19, Section 1.4, Bullet 2. Please address how specific plants having materials in containment that are not addressed by the NEI guidance would address these materials in their plant-specific analyses.
- Page 28, Section 2.6, second sentence, "The debris volume at the screen should be used to estimate the rate of accumulation of debris on the ECC sump screen." What does this sentence mean? How can a rate be estimated if our debris-transport prediction capabilities are not mature enough to predict the time-dependent accumulation of debris on the screen?
- Page 30, Section 2.8. Please include the advantages of convoluted screen designs (e.g., stacked disk strainers) as means of preventing thin-bed debris accumulations, in this paragraph.
- Page 33, Section 4.1, first paragraph, last sentence. Please include strainer geometry in addition to strainer area (e.g., "changes in strainer area and strainer geometry"). Again, strainer geometry can be useful in the prevention of thin-bed accumulations. In addition, please consider expanding on the scoping process, to directly address the potential of creating a thin-bed accumulation as was done in the parametric evaluation – i.e., ~1/8" times the screen area provides a rough estimate of the minimum volume of fiber needed to cause the high head losses associated with this type of debris bed. Comparisons of this minimum volume of debris to preliminary estimates of potential debris generation can quickly reveal potential vulnerabilities.
- Page 37, Section 4.2.1.1.1. Please consider including a minimum-pool-level analysis,

which has probably been performed at most plants, in the bullet list.

- Page 37, Section 4.2.1.1.3, 4th bullet. Explain why it is necessary to assume loss of offsite power coincident with a LOCA event. How does the loss of offsite power affect sump screen blockage? Why not perform the analyses assuming with and without loss of offsite power and then select the worst case?
- Page 39, Section 4.2.2.4. The abbreviation "HL" presumably means head loss?
- Page 48, Section 4.2.4.2.2. Please address the concern of a break occurring high in the containment, where insulation might be located below the ZOI and underneath the break and could then be damaged by the break-flow outfall.
- Page 48, Section 4.2.4.2.3. 2nd bullet. Please consider and address the presence of small suspended materials in these isolated areas, since even a small rate of flow will eventually transport suspended materials to the sump screen.
- Page 49, Section 4.2.4.2.3, 6th bullet. Should "Section 4.2.4" read "Section 4.2.5"?
- Page 50, Section 4.2.5.1. Please define the term "transportable." All forms of debris are transportable under some flow conditions – e.g., entire blankets and cassettes will move when subjected to sheet flow during sump-pool formation.
- Page 52, Section 4.2.5.3. Please consider adding a bullet to the first list explaining that the ZOI depends upon the damage pressure of the RMI, which in term depends upon the manufacturer, the attachment method and the material – i.e., whether it is Al or stainless steel. The last bullet of the second list states "...located within six pipe diameters of the break site." What is the basis for this measurement (six pipe diameters does not relate to a ZOI radius)?
- Page 54, Table 4.2.5.4.2-1. When assessing the transport of flat-plate coating debris, what are the dimensions (other than thickness) of these platelets?
- Page 56, Section 4.2.5.6, 2nd bullet. If Kaowool is the same as K-wool (from the URG) then isn't the destruction pressure known to be 40 psi (substantially higher than that for NUKON)?
- Page 61, Table 4.2.5.6-1. Please consider and address that OPG conducted tests on Marinite board that indicated edge erosion at only 5 pipe diameters, so the destruction pressure for this material is likely to be substantially higher than that for fiberglass.
- Page 64, Section 4.3.2.2. Please note that condensate drainage can also transport fine debris.
- Page 66, Section 4.3.3.2, last paragraph. Please also list "Fines."
- Page 67, Section 4.3.3.4. Please consider adding a bullet to the list that includes "stairwells" and "annular gaps".
- Page 76, Section 4.4.2.2, 2nd paragraph, "............and not at all in dead-ended compartments." Please consider and address that an exception to this statement is suspended materials. Most so-called dead-ended compartments still have some flow passing through or vortices that can transport suspended material from the region given sufficient time.
- Page 77, Section 4.4.2.3. Should "Hydraulic Processes" be a heading?
- Page 93, Table 4.4.3.4.2.5-1. Please list citations ITR-92-03N and ITR-93-02N in the references. Why are they not readily available? Should these sources of information be provided to the NRC for review and to the licensees for their use?
- Page 104, Table 4.5.2.4-1. The material density for NUKON is given as 159 lbm/ft^3, whereas the density used in NUREG/CR-6224 and in the NEI-guidance sample problem on Page 120 uses 175 lbm/ft^3. Please clarify.
- Page 108 mentions Reference 2.24. Why is it not provided in the reference list?
- Page 118, Section 4.5.3.3.2. Please develop this paragraph further, to include a

description of the application of the NUREG/CR-6224 correlation to an alternate strainer design (i.e., full screen area for an unloaded strainer vs. the circumscribed area for a fully loaded strainer) instead of just stating, "overly conservative results."

- Appendix C. The title indicates that a comparison of transport factors will be provided, but no transport factors were calculated. Only flow velocities were compared. Some discussion of transport factors would be useful. Please supplement this appendix rather than renaming to reflect the present content.

Cross-Reference Between Detailed RAI's and Preliminary Review
Of NEI's Draft
"PWR CONTAINMENT SUMP EVALUATION METHODOLOGY GUIDELINES"

Preliminary Review Item Number	Corresponding Detailed RAI's Item(s) Number(s)	Description
(p.1, ¶1)	(p.1, ¶1)	Introduction
(p.1, ¶2)	Section 1.0, Item 1	Incompleteness
(p.1, ¶3)	Section 1.0, Item 2	Conservatism
(p.1, ¶4)	Section 1.0, Item 7	Consistency and quality
(p.2, ¶1)	Section 2.1	Postulated breaks
(p.2, ¶2)	Section 1.0, Item 3	Additional testing
(p.2, ¶3)	Section 1.0, Item 6	Potential mitigation strategies
1	Section 2.2.1	ZOI mapping
2	Sections 2.2.2, Items 2 - 8 & 2.2.3, Items 1 - 6 & 2.3, Item 4 & 2.4.4, Items 7b - 7g, 7j -7n, & 7q & 2.5, Items 1 - 7	Unjustified parameters
3	Section 2.2.2, ¶1 & Item 1	Insulation destruction pressures:
3(a)	Section 2.2.2, Items 1 & 8	Single- vs. two-phase jet basis
3(b)	Section 2.2.2, Items 2 - 5, & 7	Values omitted for certain types
3(c)	Section 2.2.2, Item 6 & ¶2	Jacket seam orientation basis
4	Section 2.2.3, ¶1	Debris size distributions:
4(a)	Section 2.2.3, Item 1	NUKON applicability
4(b)	Section 2.2.3, Item 3	Particulate insulation assumptions
4(c)	Section 2.2.3, Item 4	RMI assumptions
4(d)	Section 2.2.3, Item 5	Damage data conversion to ZOI
5	Section 2.2.4	Latent debris quantification
6	Section 2.3, Item 1	Transport logic charts
7	Section 2.4.3	Debris entrance into pool
8	Section 2.4.2	Transport during pool formation
9	Section 2.4.4, Items 1 - 2	Validation of network method
10	Section 2.4.5, Item a	Velocity-based disintegration
11	Section 2.5, ¶1 & Item 1	Validation of head loss correlation
11(a)	Section 2.5, Item 2	Basis for specific surface areas
11(b)	Section 2.5, Item 3	Combined parameters for multiple constituents in debris bed
11(c)	Section 2.5, Item 4	Material-specific density
11(d)	Section 2.5, Item 6	Coefficient justification
11(e)	Section 2.5, Item 7	Water temperature considerations
11(f)	Section 2.5, Item 12	Thin-bed debris effect
11(g)	Section 2.5, Item 15	Head-loss correlations
12	Section 1.0, Item 9	Buoyant debris
13	Section 1.0, Item 8	Coating debris
14	Section 1.0, Item 5	Analytical tools and methods used

7590-01 (P)

NUCLEAR REGULATORY COMMISSION

Proposed Generic Communication

Potential Impact of Debris Blockage on Emergency Recirculation

During Design Basis Accidents at Pressurized Water Reactors

AGENCY: Nuclear Regulatory Commission.

ACTION: Notice of opportunity for public comment.

SUMMARY: The U.S. Nuclear Regulatory Commission (NRC) is proposing to issue a generic letter (GL) to request that addressees submit information to the NRC concerning the status of their compliance with 10 CFR 50.46(b)(5), which requires long-term reactor core cooling be available following a design basis loss of coolant accident, and with the additional plant-specific licensing basis requirements listed in this generic letter, in accordance with 10 CFR 50.54(f). This request is based on the identified potential susceptibility of pressurized-water reactor (PWR) recirculation sump screens to debris blockage during design basis accidents requiring recirculation operation of the emergency core cooling system (ECCS) or containment spray system (CSS) and the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and CSS recirculation and containment drainage.

This *Federal Register* notice is available through the NRC's Agencywide Documents Access and Management System (ADAMS) under accession number **ML040830518**.

DATES: Comment period expires **[60 days after FRN is published]**. Comments submitted after this date will be considered if it is practical to do so, but assurance of consideration cannot be given except for comments received on or before this date.

ADDRESSEES: Submit written comments to the Chief, Rules and Directives Branch, Division of Administrative Services, Office of Administration, U.S. Nuclear Regulatory Commission, Mail Stop T6-D59, Washington, DC 20555-0001, and cite the publication date and page number of this *Federal Register* notice. Written comments may also be delivered to NRC Headquarters, 11545 Rockville Pike (Room T-6D59), Rockville, Maryland, between 7:30 am and 4:15 pm on Federal workdays.

FOR FURTHER INFORMATION, CONTACT: David Cullison at 301-415-1212 or by email at dgc@nrc.gov or Ralph Architzel at 301-415-2804 or by email at rea@nrc.gov.

SUPPLEMENTARY INFORMATION:

DRAFT NRC GENERIC LETTER 2003-XX: POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

Addressees

All holders of operating licenses for pressurized-water nuclear power reactors, except those who have ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this generic letter to:

(1) Request that addressees submit information to the NRC to confirm compliance with 10 CFR 50.46(b)(5), which requires long-term reactor core cooling, and other existing regulatory requirements listed in this generic letter. This request is based on the identified potential susceptibility of pressurized-water-reactor (PWR) recirculation sump screens to debris blockage during design basis accidents requiring recirculation operation of the emergency core cooling system (ECCS) or containment spray system (CSS) and the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and CSS recirculation and containment drainage.

(2) Require addressees to provide the NRC a written response in accordance with 10 CFR 50.54(f).

Background

In 1979, as a result of evolving staff concerns related to the adequacy of PWR recirculation sump designs, the NRC opened Unresolved Safety Issue (USI) A-43, "Containment Emergency Sump Performance." To support the resolution of USI A-43, the NRC undertook an extensive research program, the technical findings of which are summarized in NUREG-0897, "Containment Emergency Sump Performance," dated October 1985. The resolution of USI A-43 was subsequently documented in Generic Letter (GL) 85-22, "Potential for Loss of Post-LOCA Recirculation Capability Due to Insulation Debris Blockage," dated December 3, 1985. Although the staff's regulatory analysis concerning USI A-43 did not support imposing new sump performance requirements upon licensees of operating PWRs or boiling-water reactors (BWRs), the staff recommended in GL 85-22 that all affected reactor licensees replace the 50-percent blockage assumption (under which most nuclear power plants had been licensed) with a comprehensive, mechanistic assessment of plant-specific debris blockage potential for future modifications related to sump performance, such as thermal insulation changeouts. The 50-percent screen blockage assumption does not require a plant-specific evaluation of the debris-blockage potential and may result in a non-conservative analysis for screen blockage effects. The staff also updated the NRC's regulatory guidance, including Section 6.2.2 of the Standard Review Plan (NUREG-0800) and Regulatory Guide 1.82, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," to reflect the USI A-43 technical findings documented in NUREG-0897. Following the resolution of USI A-43 in 1985, several events occurred that challenged the conclusion that no new requirements were necessary to prevent the clogging of ECCS strainers at operating BWRs:

- On July 28, 1992, at Barsebäck Unit 2, a Swedish BWR, the spurious opening of a pilot-operated relief valve led to the plugging of two containment vessel spray system suction strainers with mineral wool and required operators to shut down the spray pumps and backflush the strainers.

- In 1993, at Perry Unit 1, two events occurred during which ECCS strainers became plugged with debris. On January 16, ECCS strainers were plugged with suppression pool particulate matter, and on April 14, an ECCS strainer was plugged with glass fiber from ventilation filters that had fallen into the suppression pool. On both occasions, the affected ECCS strainers were deformed by excessive differential pressure created by the debris plugging.

- On September 11, 1995, at Limerick Unit 1, following a manual scram due to a stuck-open safety/relief valve, operators observed fluctuating flow and pump motor current on the A loop of suppression pool cooling. The licensee later attributed these indications to a thin mat of fiber and sludge which had accumulated on the suction strainer.

In response to these ECCS suction strainer plugging events, the NRC issued several generic communications, including Bulletin 93-02, Supplement 1, "Debris Plugging of Emergency Core Cooling Suction Strainers," dated February 18, 1994, Bulletin 95-02, "Unexpected Clogging of a Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode," dated October 17, 1995, and Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors," dated May 6, 1996.

These bulletins requested that BWR licensees implement appropriate procedural measures, maintenance practices, and plant modifications to minimize the potential for the clogging of ECCS suction strainers by debris accumulation following a loss-of-coolant accident (LOCA). The NRC staff has concluded that all BWR licensees have sufficiently addressed these bulletins.

However, findings from research to resolve the BWR strainer clogging issue have raised questions concerning the adequacy of PWR sump designs. In comparison to the technical findings of the USI A-43 research program concerning PWRs, the research findings demonstrate that the amount of debris generated by a high-energy line break (HELB) could be greater, that the debris could be finer (and, thus, more easily transportable), and that certain combinations of debris (e.g., fibrous material plus particulate material) could result in a substantially greater head loss than an equivalent amount of either type of debris alone. These research findings prompted the NRC to open Generic Safety Issue (GSI) 191, "Assessment of Debris Accumulation on PWR Sump Performance." The objective of GSI-191 is to ensure that post-accident debris blockage will not impede or prevent the operation of the ECCS and CSS in recirculation mode at PWRs during LOCAs or other HELB accidents for which sump recirculation is required.

On June 9, 2003, having completed its technical assessment of GSI-191 (summarized below in the Discussion section of this generic letter), the NRC issued Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors." As a result of the emergent issues discussed therein, the bulletin requested an expedited response from PWR licensees as to the status of their compliance on a mechanistic basis, with regulatory requirements concerning the ECCS and CSS recirculation functions. Addressees who were unable to assure regulatory compliance pending further analysis were asked to describe any interim compensatory measures that have been implemented or will be implemented to reduce risk until the analysis could be completed. All licensees have since responded to Bulletin 2003-01. In developing Bulletin 2003-01, the NRC staff recognized that it may be necessary for addressees to undertake complex evaluations to determine whether regulatory compliance exists in light of the concerns identified in the bulletin and that the methodology to perform such evaluations was not currently available. As a result, that information was not requested in the bulletin but addressees were informed that the staff was preparing a generic letter that would request this information. This generic letter is the follow-on information request referenced in the bulletin.

In response to Bulletin 2003-01, PWR licensees that were unable to confirm regulatory compliance implemented or plan to implement compensatory measures to reduce risk or otherwise enhance the capability of the ECCS and CSS recirculation functions. During the process of resolving the potential concerns identified in this generic letter, the revised analysis of sump performance may affect addressees' understanding of their facilities' ECCS and CSS recirculation capabilities. In accordance with GL 91-18, Revision 1, "Information to Licensees Regarding NRC Inspection Manual Section on Resolution of Degraded and Nonconforming Conditions," dated October 8, 1997, addressees may find it necessary to reevaluate the adequacy of their compensatory measures in light of the new information and take further action as appropriate and necessary. Upon resolution of the potential concerns identified in this generic letter and the completion of any corrective actions resulting from that resolution, addresses may consider continuing, revising, or retiring their compensatory measures as appropriate.

The NRC has developed a Web page to keep the public informed of generic activities on PWR sump performance (http://www.nrc.gov/reactors/operating/ops-experience/pwr-sump-performance.html). This page provides links to information on PWR sump performance issues, along with documentation of NRC interactions with industry (industry submittals, meeting notices, presentation materials, and meeting summaries). The NRC will continue to update this Web page as new information becomes available.

Discussion

In the event of a HELB inside the containment of a PWR, energetic pressure waves and fluid jets would impinge upon materials in the vicinity of the break, such as thermal insulation, coatings, and concrete, causing them to become damaged and dislodged. Debris could also be generated through secondary mechanisms, such as severe post-accident temperature and humidity conditions, flooding of the lower containment, and the impact of containment spray droplets. In addition to debris generated by jet forces from the pipe rupture, debris can be created by the chemical reaction between the chemically reactive spray solutions used following a LOCA and the materials in containment. These reactions may result in additional debris such as disbonded coatings and chemical precipitants being generated. Through transport methods such as entrainment in the steam/water flows issuing from the break and containment spray washdown, a fraction of the generated debris and foreign material in the containment would be transported to the pool of water formed on the containment floor. Subsequently, if the ECCS or

CSS pumps were to take suction from the recirculation sump, the debris suspended in the containment pool would begin to accumulate on the sump screen or be transported through the associated system. The accumulation of this suspended debris on the sump screen could create a roughly uniform covering on the screen, referred to as a debris bed, which would tend to increase the head loss across the screen through a filtering action. If a sufficient amount of debris were to accumulate, the debris bed would reach a critical thickness at which the head loss across the debris bed would exceed the net positive section head (NPSH) margin required to ensure the successful operation of the ECCS and CSS pumps in recirculation mode. A loss of NPSH margin for the ECCS or CSS pumps as a result of the accumulation of debris on the recirculation sump screen, referred to as sump clogging, could result in degraded pump performance and eventual pump failure. Debris could also plug or wear close tolerance components within the ECCS or CSS systems. The effect of this plugging or wear may cause a component to degrade to the point where it may be unable to perform its designated function (i.e. pump fluid, maintain system pressure, or pass and control system flow.)

Assessing the likelihood of the ECCS and CSS pumps at domestic PWRs experiencing a debris-induced loss of NPSH margin during sump recirculation was the primary objective of the NRC's technical assessment of GSI-191. The NRC's technical assessment culminated in a parametric study that mechanistically treated phenomena associated with debris blockage using analytical models of domestic PWRs generated with a combination of generic and plant-specific data. As documented in Volume 1 of NUREG/CR-6762, "GSI-191 Technical Assessment: Parametric Evaluations for Pressurized Water Reactor Recirculation Sump Performance," dated August 2002, the GSI-191 parametric study concludes that recirculation sump clogging is a credible concern for domestic PWRs. As a result of limitations with respect to plant-specific data and other modeling uncertainties, however, the parametric study does not definitively identify whether or not particular PWR plants are vulnerable to sump clogging when phenomena associated with debris blockage are modeled mechanistically.

The methodology employed by the GSI-191 parametric study is based upon the substantial body of test data and analyses that are documented in technical reports generated during the NRC's GSI-191 research program and earlier technical reports generated by the NRC and the industry during the resolution of the BWR strainer clogging issue and USI A-43. These pertinent technical reports, which cover debris generation, transport, accumulation, and head loss, are incorporated by reference into the GSI-191 parametric study:

- NUREG/CR-6770, "GSI-191: Thermal-Hydraulic Response of PWR Reactor Coolant System and Containments to Selected Accident Sequences," dated August 2002.

- NUREG/CR-6762, Vol. 3, "GSI-191 Technical Assessment: Development of Debris Generation Quantities in Support of the Parametric Evaluation," dated August 2002.

- NUREG/CR-6762, Vol. 4, "GSI-191 Technical Assessment: Development of Debris Transport Fractions in Support of the Parametric Evaluation," dated August 2002.

- NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," dated October 1995.

In light of the credibility of the concerns identified above, the NRC staff has determined that it is appropriate to request that addressees submit information to confirm their plant-specific compliance with NRC regulations and other existing regulatory requirements listed in this generic letter pertaining to post-accident debris blockage. If addressees perform an analysis to confirm compliance, the NRC staff recommends the use of an analysis method that mechanistically accounts for debris generation and transport, post accident equipment and systems operation with debris laden fluid.

In addition to demonstrating the potential for debris to clog containment recirculation sumps, operational experience and the NRC's technical assessment of GSI-191 have also identified three integrally related modes by which post-accident debris blockage could adversely affect the sump screen's design function of intercepting debris that could impede or prevent the operation of the ECCS and CSS in recirculation mode.

First, as a result of the 50-percent blockage assumption, most PWR sump screens were designed assuming that relatively small structural loadings would result from the differential pressure associated with debris blockage. Consequently, PWR sump screens may not be capable of accommodating the increased structural loadings that would occur due to mechanistically determined debris beds that cover essentially the entire screen surface. Inadequate structural reinforcement of a sump screen may result in its deformation, damage, or failure, which could allow large quantities of debris to be ingested into the ECCS and CSS piping, pumps, and other components, potentially leading to their clogging or failure. The ECCS strainer plugging and deformation events that occurred at Perry Unit 1 (further described in Information Notice (IN) 93-34, "Potential for Loss of Emergency Cooling Function Due to a

Combination of Operational and Post-LOCA Debris in Containment," dated April 26, 1993, and LER 50-440/93-011, "Excessive Strainer Differential Pressure Across the RHR Suction Strainer Could Have Compromised Long Term Cooling During Post-LOCA Operation," submitted May 19, 1993), demonstrate the credibility of this concern for screens and strainers that have not been designed with adequate reinforcement.

Second, in some PWR containments, the flowpaths by which containment spray or break flows return to the recirculation sump may include "choke-points," where the flowpath becomes so constricted that it could become blocked with debris following a HELB. Examples of potential choke-points are drains for pools, cavities, isolated containment compartments, and constricted drainage paths between physically separated containment elevations. Debris blockage at certain choke-points could hold up substantial amounts of water required for adequate recirculation or cause the water to be diverted into containment volumes that do not drain to the recirculation sump. The holdup or diversion of water assumed to be available to support sump recirculation could result in an available NPSH for ECCS and CSS pumps that is lower than the analyzed value, thereby reducing assurance that recirculation would successfully function. A reduced available NPSH directly concerns sump screen design because the NPSH margin of the ECCS and CSS pumps must be conservatively calculated to determine correctly the required surface area of passive sump screens when mechanistically determined debris loadings are considered. Although the parametric study (NUREG/CR-6762, Volume 1) did not analyze in detail the potential for the holdup or diversion of recirculation sump inventory, the NRC's GSI-191 research identified this phenomenon as an important and potentially credible concern. A number of LERs associated with this concern have also been generated, which further confirms its credibility and potential significance:

- LER 50-369/90-012, "Loose Material Was Located in Upper Containment During Unit Operation Because of an Inappropriate Action," McGuire Unit 1, submitted August 30, 1990.

- LER 50-266/97-006, "Potential Refueling Cavity Drain Failure Could Affect Accident Mitigation," Point Beach Unit 1, submitted February 19, 1997.

- LER 50-455/97-001, "Unit 2 Containment Drain System Clogged Due to Debris," Byron Unit 2, submitted April 17, 1997.

- LER 50-269/97-010, "Inadequate Analysis of ECCS Sump Inventory Due to Inadequate Design Analysis," Oconee Unit 1, submitted January 8, 1998.

- LER 50-315/98-017, "Debris Recovered from Ice Condenser Represents Unanalyzed Condition," D.C. Cook Unit 1, submitted July 1, 1998.

Third, debris blockage at flow restrictions within the ECCS recirculation flowpath downstream of the sump screen is a potential concern for PWRs. Debris that is capable of passing through the recirculation sump screen may have the potential to become lodged at a downstream flow restriction, such as a high-pressure safety injection (HPSI) throttle valve or fuel assembly inlet debris screen. Debris blockage at such flow restrictions in the ECCS flowpath could impede or prevent the recirculation of coolant to the reactor core, thereby leading to inadequate core cooling. Similarly, debris blockage at flow restrictions in the CSS flowpath, such as a containment spray nozzle, could impede or prevent CSS recirculation, thereby leading to inadequate containment heat removal. Debris may also accumulate in close tolerance sub-components of pumps and valves. The effect may either be to plug the sub-component thereby rendering the component unable to perform its function or to wear critical close tolerance sub-components to the point at which component or system operation is degraded and unable to fully perform its function. Considering the recirculation sump screen's design function of intercepting potentially harmful debris, it is essential that the screen openings are adequately sized and that the sump screen's current configuration is free of gaps or breaches which could compromise the ECCS and CSS recirculation functions. It is also essential that system components are designed and evaluated to be able to operate with debris laden fluid as necessary post-LOCA.

To assist in determining on a plant-specific basis whether compliance exists with 10 CFR 50.46(b)(5), addressees may use the guidance contained in Regulatory Guide 1.82 (RG 1.82), Revision 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," dated November 2003. Revision 3 enhanced the debris blockage evaluation guidance for pressurized water reactors provided in Revision 1 of the regulatory guide. The NRC staff determined after the issuance of Revision 2 that research for PWRs indicated that the guidance in that revision was not comprehensive enough to ensure adequate evaluation of a PWR plant's susceptibility to the detrimental effects caused by debris accumulation on debris interceptors (e.g., trash racks and sump screens). Revision 2 altered the debris blockage evaluation guidance found in Revision 1 following the evaluation of blockage events, such as the Barsebäck Unit 2 event mentioned above, but for BWRs only. Revision 1 replaced the 50-percent blockage assumption in Revision 0 with a comprehensive, mechanistic assessment of plant-specific debris blockage potential for future modifications related to sump performance, such as thermal insulation changeouts. This was in response to the findings of USI A-43. In addition, the NRC staff is reviewing generic industry guidance and will issue a safety evaluation report endorsing portions or all of the generic industry guidance, if found acceptable. Once approved, this guidance may also be used to assist in determining the status of regulatory compliance. Individual addressees may also develop alternative approaches to those named in this paragraph for determining the status of their regulatory compliance; however, additional staff review may be required to assess the adequacy of such approaches. If the industry guidance will not be available when the generic letter is issued, the NRC will provide additional guidance for determining on a plant-specific basis whether compliance exists with 10 CFR 50.46(b)(5).

The time frames for addressee responses in this generic letter were selected to 1) allow adequate time for addresses to perform an analysis, if they opt to do so, 2) allow addressees to properly design and install any identified modifications, 3) allow addresses adequate time to obtain NRC approval, as necessary, for any licensing basis changes, and 4) allow for the closure of the generic issue in accordance with the published schedule. These time frames are appropriate since all addresses have responded to Bulletin 2003-01 and will, if necessary, implement compensatory measures until the issues identified in this generic letter are resolved.

Applicable Regulatory Requirements

NRC regulations in Title 10, of the *Code of Federal Regulations* Section 50.46,(10 CFR 50.46), require that the ECCS must satisfy five criteria, one of which is to provide the capability for long-term cooling of the reactor core following a LOCA. The ECCS must have the capability to provide decay heat removal, such that the core temperature is maintained at an acceptably low value for the extended period of time required by the long-lived radioactivity remaining in the core. For PWRs licensed to the General Design Criteria (GDCs) in Appendix A to 10 CFR Part 50, GDC 35 specifies additional ECCS requirements.

Similarly, for PWRs licensed to the GDCs in Appendix A to 10 CFR Part 50, GDC 38 provides requirements for containment heat removal systems, and GDC 41 provides requirements for containment atmosphere cleanup. Many PWR licensees credit a CSS, at least in part, with performing the safety functions to satisfy these requirements, and PWRs that are not licensed to the GDCs may similarly credit a CSS to satisfy licensing basis requirements. In addition, PWR licensees may credit a CSS with reducing the accident source term to meet the limits of 10 CFR Part 100 or 10 CFR 50.67.

Criterion XVI (Corrective Action) of Appendix B to 10 CFR Part 50 states that measures shall be established to assure that conditions adverse to quality are promptly identified and corrected. For significant conditions adverse to quality, the measures taken shall include root cause determination and corrective action to preclude repetition of the adverse conditions.

If, in the course of preparing a response to the requested information, an addressee determines that its facility is not in compliance with the Commission's requirements, the addressee is expected to take appropriate action in accordance with requirements of Appendix B to 10 CFR Part 50 and the plant technical specifications to restore the facility to compliance.

Applicable Regulatory Guidance[1]

Regulatory Guide 1.82, Revision 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident," November 2003.

Requested Information

All addressees are requested to provide the following information:

1. Within 60 days of the date of this generic letter, addressees provide information regarding their planned actions and schedule to confirm their compliance with 10 CFR 50.46(b)(5) and other existing regulatory requirements listed in this generic letter. The provided information should include the following:

   (a) A description of the methodology used or that will be used to analyze the susceptibility of the ECCS and CSS recirculation functions for your reactor to adverse effects of post-accident debris blockage and operation with debris laden fluids identified in this generic letter. Provide the completion date of any analysis that will be performed.

   (b) If a mechanistic analysis was or will be performed to confirm compliance, provide a statement of whether or not you plan to perform a containment walkdown surveillance in support of the analysis of the susceptibility of the ECCS and CSS

1 The NRC staff is currently reviewing evaluation guidance developed by the industry. The NRC staff will document its review in a safety evaluation which licensees can reference as regulatory guidance.

recirculation functions to the adverse effects of debris blockage identified in this generic letter. Provide justification if no containment walkdown surveillance will be performed. If a containment walkdown surveillance will be performed, state the planned methodology to be used and the planned completion date. If a containment walkdown surveillance has already been performed, state the methodology used, the completion date, and the results of the surveillance.

2. Addresses are requested to provide no later than April 1, 2005, information that confirms their compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter.

   (a) Provide 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 generic letter. This submittal should also address the configuration of the plant that will exist once all modifications required for regulatory compliance have been made.

   (b) A general description of and implementation schedule for all corrective actions, including any plant modifications that may be necessary to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter. Provide justification for any corrective action that will not be completed by the end of the first refueling outage after April 1, 2005.

(c) A submittal that describes the methodology that was used to perform an analysis of the susceptibility of the ECCS and CSS recirculation functions to the adverse effects of post-accident debris blockage and operation with debris laden fluids. The submittal may reference a guidance document (e.g. Regulatory Guide 1.82, industry guidance) or other methodology previously submitted to the NRC. If a mechanistic analysis was performed to confirm compliance, the documents to be submitted or referenced should include the methodology for conducting a supporting containment walkdown surveillance used to identify potential debris sources and other pertinent containment characteristics.

(d) If a mechanistic analysis was performed to confirm compliance, the submittal should include, at a minimum, the following information:

(I) The minimum available NPSH margin for the ECCS and CSS pumps with an unblocked sump screen.

(ii) The extent of submergence of the sump screen (i.e., partial or full) at the time of the switchover to sump recirculation, and the submerged area of the sump screen at this time.

(iii) The maximum head loss postulated from debris accumulation on the submerged sump screen, and a description of the primary constituents of the debris bed that result in this head loss. In addition to debris generated by jet forces from the pipe rupture, debris created by the resulting containment environment (thermal and chemical) and CSS washdown should be considered in the analyses. Examples of this type of debris are disbonded coatings in the form of chips and particulates or chemical precipitants caused by chemical reactions in the pool.

(iv) The basis for concluding that 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.

(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, such as 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.

(vi) Verification that close tolerance sub-components 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.

(vii) If an active approach (e.g. back flushing, powered screens, etc.) is selected in lieu of or in addition to a passive approach to mitigate the effects of the debris blockage, describe the approach and associated analyses.

(e) A general description of and planned schedule for any changes to the plant licensing bases resulting from any analysis or plant modification done to ensure compliance with the regulatory requirements listed in the Applicable Regulatory Requirements section of this generic letter.

(f) A description of any existing or planned programmatic controls that will ensure that, in the future, 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 to the extent that their responses address these specific foreign material control issues.

Required Response

In accordance with 10 CFR 50.54(f), the subject PWR addressees are required to submit written responses to this generic letter. This information is sought to verify licensees' compliance with current licensing basis for the subject PWR addressees. The addressees have two options:

(1) addressees may choose to submit written responses providing the information requested above within the requested time periods, or

(2) addressees who choose not to provide information requested or cannot meet the requested completion dates are required to submit written responses within 15 days of the date of this generic letter. The responses must address any alternative course of action proposed, including the basis for the acceptability of the proposed alternative course of action.

The required written responses should be addressed to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, 11555 Rockville Pike, Rockville, Maryland 20852, under oath or affirmation under the provisions of Section 182a of the Atomic Energy Act of 1954, as amended, and 10 CFR 50.54(f). In addition, a copy of a response should be submitted to the appropriate regional administrator.

The NRC staff will review the responses to this generic letter and will notify affected addressees if concerns are identified regarding compliance with NRC regulations and their current licensing bases. The staff may also conduct inspections to determine addressees' effectiveness in addressing the generic letter.

<u>Reasons for Information Request</u>

As discussed above, research and analysis suggests that (1) the potential for the failure of the ECCS and CSS recirculation functions as a result of debris blockage is not adequately addressed in most PWR licensees' current safety analyses, and (2) the ECCS and CSS recirculation functions at a significant number of operating PWRs could become degraded as a result of the potential effects of debris blockage or extended operation with debris laden fluids identified in this generic letter. An ECCS that is incapable of providing long-term reactor core cooling through recirculation operation would be in violation of 10 CFR 50.46. A CSS that is incapable of functioning in recirculation mode may not comply with GDCs 38 and 41 or other plant-specific licensing requirements or safety analyses. Bulletin 2003-01 requested information to verify addressees' compliance with NRC regulations and to ensure that any interim risks associated with post-accident debris blockage are minimized while evaluations to determine compliance proceed. This generic letter is the follow-on generic communication to Bulletin 2003-01 which is requesting information on the results of the evaluations referenced in the bulletin. Therefore, the information requested in this generic letter is necessary to confirm plant-specific compliance with 10 CFR 50.46 and other existing regulations.

The NRC staff will also use the requested information to (1) determine whether a sample auditing approach is acceptable for verifying that addressees have resolved the concerns identified in this generic letter, (2) assist in determining which addressees would be subject to the proposed sample audits, (3) provide confidence that any nonaudited addressees have addressed the concerns identified in this generic letter, and (4) assess the need for and guide the development of any additional regulatory actions that may be necessary to address the adequacy of the ECCS and CSS recirculation functions.

Related Generic Communications

- Bulletin 2003-01, "Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors," June 9, 2003.
- Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors," May 6, 1996.
- Bulletin 95-02, "Unexpected Clogging of a Residual Heat Removal (RHR) Pump Strainer While Operating in the Suppression Pool Cooling Mode," October 17, 1995.
- Bulletin 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers," May 11, 1993.
- Bulletin 93-02, Supplement 1, "Debris Plugging of Emergency Core Cooling Suction Strainers," February 18, 1994.
- Generic Letter 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," July 14, 1998.
- Generic Letter 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," October 7, 1997.

- Generic Letter 85-22, "Potential For Loss of Post-LOCA Recirculation Capability Due to Insulation Debris Blockage," December 3, 1985.

- Information Notice 97-13, "Deficient Conditions Associated With Protective Coatings at Nuclear Power Plants," March 24, 1997.

- Information Notice 96-59, "Potential Degradation of Post Loss-of-Coolant Recirculation Capability as a Result of Debris," October 30, 1996.

- Information Notice 96-55, "Inadequate Net Positive Suction Head of Emergency Core Cooling and Containment Heat Removal Pumps Under Design Basis Accident Conditions," October 22, 1996.

- Information Notice 96-27, "Potential Clogging of High Pressure Safety Injection Throttle Valves During Recirculation," May 1, 1996.

- Information Notice 96-10, "Potential Blockage by Debris of Safety System Piping Which Is Not Used During Normal Operation or Tested During Surveillances," February 13, 1996.

- Information Notice 95-47, "Unexpected Opening of a Safety/Relief Valve and Complications Involving Suppression Pool Cooling Strainer Blockage," October 4, 1995.

- Information Notice 95-47, Revision 1, “Unexpected Opening of a Safety/Relief Valve and Complications Involving Suppression Pool Cooling Strainer Blockage,” November 30, 1995.

- Information Notice 95-06, “Potential Blockage of Safety-Related Strainers by Material Brought Inside Containment,” January 25, 1995.

- Information Notice 94-57, “Debris in Containment and the Residual Heat Removal System,” August 12, 1994.

- Information Notice 93-34, “Potential for Loss of Emergency Cooling Function Due to a Combination of Operational and Post-LOCA Debris in Containment,” April 26, 1993.

- Information Notice 93-34, Supplement 1, “Potential for Loss of Emergency Cooling Function Due to a Combination of Operational and Post-LOCA Debris in Containment,” May 6, 1993.

- Information Notice 92-85, “Potential Failures of Emergency Core Cooling Systems Caused by Foreign Material Blockage,” December 23, 1992.

- Information Notice 92-71, “Partial Plugging of Suppression Pool Strainers at a Foreign BWR,” September 30, 1992.

- Information Notice 89-79, "Degraded Coatings and Corrosion of Steel Containment Vessels," December 1, 1989.

- Information Notice 89-79, Supplement 1, "Degraded Coatings and Corrosion of Steel Containment Vessels," June 29, 1990.

- Information Notice 89-77, "Debris in Containment Emergency Sumps and Incorrect Screen Configurations," November 21, 1989.

- Information Notice 88-28, "Potential for Loss of Post-LOCA Recirculation Capability Due to Insulation Debris Blockage," May 19, 1988.

Backfit Discussion

Under the provisions of Section 182a of the Atomic Energy Act of 1954, as amended, and 10CFR 50.54(f), this generic letter transmits an information request for the purpose of verifying compliance with existing applicable regulatory requirements (see the Applicable Regulatory Requirements section of this generic letter). Specifically, the required information will enable the NRC staff to determine whether the emergency core cooling system (ECCS) and containment spray system (CSS) at reactor facilities are able to perform their safety functions following all postulated accidents for which ECCS or CSS recirculation is required while taking into account the adverse effects of post-accident debris blockage and operation with debris laden fluids. No backfit is either intended or approved by the issuance of this generic letter, and the staff has not performed a backfit analysis.

Small Business Regulatory Enforcement Fairness Act

The NRC has determined that this generic letter is not subject to the Small Business Regulatory Enforcement Fairness Act of 1996.

Federal Register Notification

The NRC published a notice of opportunity for public comment on this generic letter in the *Federal Register* on .... In addition, the NRC has provided opportunities for public comment at several public meetings. As the resolution of this matter progresses, the NRC will continue to provide opportunities for further public involvement.

Paperwork Reduction Act Statement

This generic letter contains information collections that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). These information collections were approved by the Office of Management and Budget (OMB) under approval number XXXX-XXXX which expires on XXX XX, XXXX.

The burden to the public for these mandatory information collections is estimated to average 1000 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the necessary data, and completing and reviewing the information collections. Send comments regarding this burden estimate or any other aspect of these information collections, including suggestions for reducing the burden, to the Records Management Branch, Mail Stop T-6 E6, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by Internet electronic mail to INFOCOLLECTS@NRC.GOV; and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202 (3150-0011), Office of Management and Budget, Washington, DC 20503.

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Dated at Rockville, Maryland, this xxth day of May 2003

FOR THE NUCLEAR REGULATORY COMMISSION

William D. Beckner, Program Director
Operating Reactor Improvements
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation