Nuclear Energy Institute PWR Sump Performance Task Force
Program to Address
Degradation of ECCS Performance by Sump Blockage

Evaluation Methodology Ground Rules
DRAFT 10-18-2002

I Objective

This document establishes programmatic and technical ground rules for the development of an evaluation methodology to address the potential for containment sump screen blockage following a design basis event. This evaluation methodology (EM) will be used in support of plant specific evaluations that address concerns identified in NRC Generic Safety Issue (GSI) 191.

The evaluation methodology and associated evaluation tools are intended to provide utilities with guidance to quantitatively determine plant susceptibility to the potential for degraded ECCS performance by debris accumulation on the containment sump screen with consequential loss of ECCS/Containment Spray NPSH. The evaluation methodology will also provide utilities with general guidance on actions that can be taken to ensure ECCS operability during design basis events.

The programmatic ground rules described in Section II are the principle set of considerations upon which the evaluation methodology will be based. These high level considerations help define the boundaries within which the methodology applies.

Section III presents the principal technical considerations and assumptions upon which the evaluation methodology will be developed. Detailed technical assumptions and quantitative correlations based on these technical considerations will be established as part of the methodology development effort.

II Program Ground Rules

1. Initiating Events Considered within EM Scope

   The evaluation methodology will be developed in consideration of all design basis initiating events that require ECCS operation in the recirculation mode to successfully mitigate that design basis event. The program methodology recognizes that LOCA is the principal initiating event and that sump function is necessary to comply with the evaluation criteria of 10CFR50.46. Other design basis events, such as Main Steam Line Break, which necessitate recirculation flow from the containment sump, will be evaluated using methods, assumptions, and inputs typical for those analyses. Events that are beyond design basis will not be addressed as part of the evaluation methodology.

   The methodology includes the consideration of all events that require ECCS operation in the recirculation mode, but focus is upon LOCA events. This is warranted since LOCA events are the most risk-significant due to their

ATTACHMENT 2

combination of the requirement to cool the core with the potential for release of significant radionuclides.

2. Application of Single Failure Assumption

   Consideration of the initiating event will be based on current design analysis principles. Component and system failure will be limited to credible single failure scenarios. Only one limiting failure will be applied to the entire analysis, and the effects of that failure will be consistently applied to all phases of the plant response. Expected non-faulted system initial conditions, timing, and operating characteristics will be assumed.

3. EM Scope to Address Containment Sump Performance

   The evaluation methodology will assess the effect of debris accumulation on the containment sump screen relative to the operation of the ECCS and containment spray system. Other considerations (e.g., structural integrity, fuel performance) are beyond the scope of the evaluation methodology.

4. EM Scope to Address Materials Typically Used in Industry Applications

   The evaluation methodology will address materials typically used in the industry as insulation and coating materials. The guidance will not necessarily explicitly consider or assess the generation, transport, or accumulation characteristics of non-traditional materials (i.e., materials used in a single plant or rare applications).

5. Application of Risk-Informed Considerations

   Program methodology will be developed primarily using deterministic methods. Risk-informed considerations, where practical and defensible, may also be used. It is anticipated that such considerations may be employed in establishing initial conditions, timing and operating characteristics of plant systems and components.

6. Validity of Supporting Data

   Data employed in the development of the EM or applied directly through the EM may not have been produced under a 10CFR50, Appendix B program. Such data will be carefully evaluated through a validation and verification process that may include analytical methods such as comparison to theoretical predictions or to other similar but independent empirical results.

III General Technical Considerations

1. Debris Generation

   1.1. Potential Pipe Break Locations

   1.2 Debris Types, Location, Amounts

   1.3 Break Jet Destruction Model

   1.4 Type, Volume and Size Distribution of Debris Generated

   Insulation

   Coatings

2 Debris Transport

- 2.1 Volume of Debris Introduced
  - 2.1.1 Insulation
  - 2.1.2 Coatings
  - 2.1.3 Other Particulates or Materials Present
- 2.2 Debris Transport Characteristics
- 2.3 Containment Flood-up Characterization
- 2.4 Intervening Structures

3 Sump Blockage

- 3.1 Debris Materials Transported to Sump
- 3.2 Transient Buildup of Debris on Sump
- 3.3 Debris Pressure Drop
- 3.4 Head Loss Incurred Across Debris Bed

4 NPSH Calculation

- 4.1 Containment Overpressure

5 Operator, Design and System Response Considerations

- 5.1 ECCS Flow
- 5.2 Event Duration

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Subject: **Head Loss Behavior on ECCS Screens and Strainers from Fibers and Particulates**

The purpose of this letter is to bring to the forefront of the NRC what PCI believes is the need for a better understanding of how head losses across the ECCS screens are affected by fibrous debris and particulate. Unless this relationship is clearly understood by the PWR plant staffs, actions may be implemented that are not in the best interest of the plants.

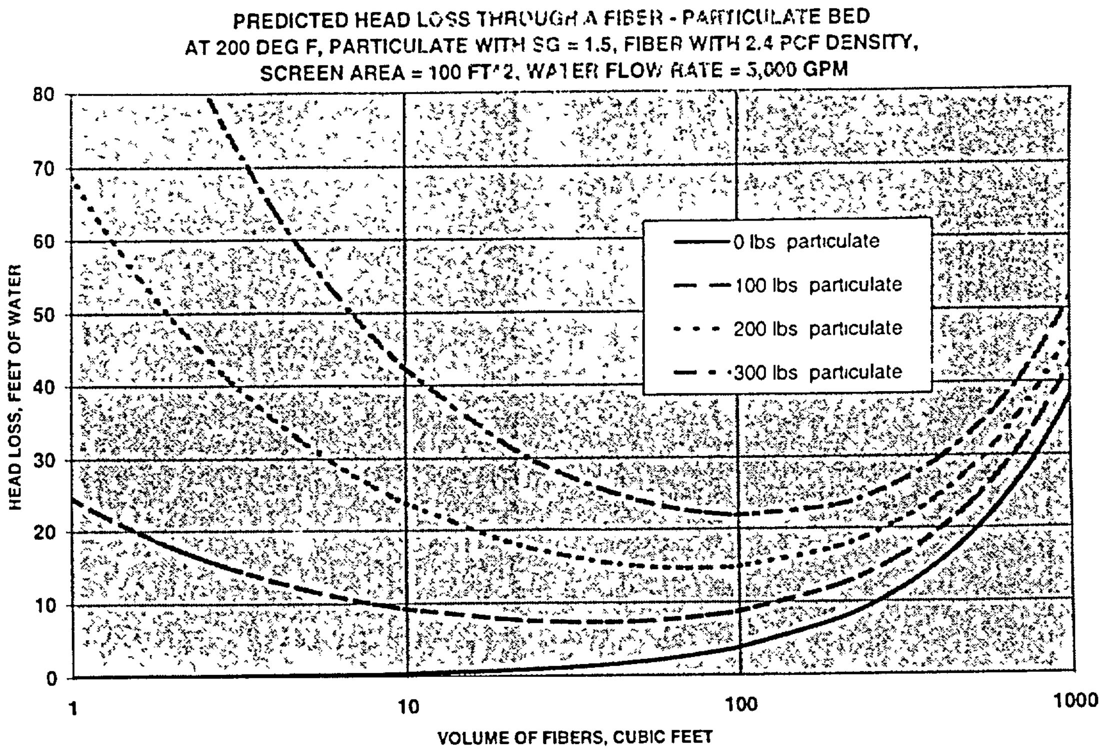
Generally speaking, we have found that many PWR plant personnel believe head loss across the ECCS screens will always be less if they reduce the volume of fibrous debris in their containments. In consequence to this belief, we have also found that it comes as a great surprise to learn that this statement is inaccurate, and, in fact, can lead to decisions that have costly consequences that do nothing to correct, or even improve, the post-LOCA ECCS screen blockage problem at PWR plants.

In the mid 90's, your agency issued NUREG/CR-6367, Experimental Study of Head Loss and Filtration for LOCA Debris. This study details the testing and analyses used by the your contractors to develop a generalized head loss equation for fibers with particulates. For one type of fibrous material and one type of particulate, your contractors derived the following head loss equation:

$$\Delta H / \Delta L_o = A\,(1 + 0.54\eta)^{1.5}\,U + 4\,(1 + 0.54\,\eta)\,U^2$$

where A = 10 for 60° F water and A = 5 for 120° F water,
η = particulate to fiber mass ratio (on the screen),
U = water velocity approaching the screen, feet per second,
ΔL_o = thickness of NUKON debris bed, inches,
ΔH = head loss across the debris bed, feet of water.

In using this equation to calculate head loss as a function of fibrous debris quantity, and making a correction for lower specific gravity particulates, such as that from paint chips, (SG of iron oxide is 5.2) one can generate the following graph using a spread sheet for several different particulate and fibrous debris quantities:



The design conditions identified on the above graph are representative for many US PWR plants. I began the graph at 1 ft^3 of fibrous debris because on a 100 ft^2 screen, that corresponds to a debris bed thickness of 1/8 inch. Your contractors have shown that debris beds have not yet formed until the fiber bed is at least 1/8 inch thick.

As can be seen from the graph above, the relationship between fibers with particulates and head loss is not intuitive. For example, it clearly shows that a very small volume of fibers with a given level of particulates will cause much higher head losses than a moderate level of fibers. Most people initially see this as illogical. Intuitively, most plant personnel generally believe that less fibrous debris is always better than more fibrous debris. Herein lies the root of a misunderstanding that we believe is so widespread. The curves on the above graph, based on the NUREG/CR-6367 head loss equation, are typical and are applicable for the post-LOCA ECCS design conditions of PWR plants.

To further illustrate this point using the above graph, it is clear that a fibrous debris bed of around 100 ft^3 yields the lowest head loss for the specific design conditions above (depending on quantity of particulate). If we reduce fibrous debris to say 5 ft^3, such as by removing fiberglass insulation from inside containment, the head loss increases from ~ 22 feet to something more than 50 feet of head loss with a particulate level of only 300 lbs.

And so, contrary to the logic that fewer fibers will lower the head loss, fewer fibers will actually increase the head loss across 100 ft^2 ECCS screens, up to about 100 ft^3 of fibers. If we test the other end of the graph, and increase fiber volume to 1,000 ft^3, the head loss is about 52 feet with 300 lbs. of particulate. Compared to our starting point of 100 ft^3 of fibrous debris, the intuitive logic holds true since head loss increases when fibers are added to the debris on the screens. But it is not true when compared to any volume of fiber that is left of the optimum volume, or to the left of about 100 ft^3.

The reality is that any volume of fibrous debris that is "less than optimum" or "more than optimum" will increase the head loss across the ECCS screen. To shed some light on this issue, please consider the following: we understand that the default values for non-insulation debris accepted by the NRC, and listed in the BWROG URG for dirt, dust ,rust flakes, and paint in the Zone of Influence (ZOI), is 285 lbs. The default values for latent fiber (fibers from clothes, hair, etc.), used by many BWR plants in addressing Bulletin 96-03, was usually around 5 to 10 ft^3. We understand that your agency has accepted this range of latent fiber volume in BWR plant specific ECCS evaluations. We would not expect a default value of 0 ft^3 latent fiber to be justifiable to your agency under any condition, regardless of the cleanliness of a containment. And, our studies indicate that this BWR URG default value will probably be scaled higher for PWR's due to the greater size of PWR containments. If the NRC staff views these conditions to be different than we have stated them herein, then we stand corrected.

In a post-LOCA condition, one would expect to add fiberglass insulation debris, and other fibrous bearing materials as may exist in containments, to the "latent fiber". PCI estimates that a PWR plant insulated with NUKON Insulation on all NSSS equipment may transport from 100 ft^3 to 300 ft^3 to the ECCS screens following a LOCA, dependent on plant specific and break specific factors. Conversely, a plant's containment piping and equipment insulated 100% with reflective metallic insulation (RMI), the RMI will not add any fibers to the debris mix, and so the value for latent fibers becomes the total volume of fibrous debris. As can be seen above, if the only fibrous debris that exists is latent fibers, the head loss can be expected to be very high. This is not intuitive, which is why I believe there is significant misunderstanding in the industry of this head loss – fibrous debris volume relationship.

To give you some concept of the damage this misunderstanding can cause, as I write this letter there is a US PWR plant where the personnel are removing all fibrous insulation materials so they can attain a "fiber free" plant. Of course with 1 to 10 ft^3 of miscellaneous fiber still remaining, it is easy to show that they will have a post-LOCA head loss greater than if they left their fibrous insulation intact. Their plant management has made this decision because they misunderstand the issue, which makes my point. There is an urgent need for plant personnel, and their management, to better understand this technical issue.

And so, in conclusion, I am urging the NRC to assist in remedying the widespread misunderstanding of the dependency of head loss on volume of fibrous debris and particulates. I suggest that you do this in future public meetings or workshops in which you and your contractors participate. PCI's representative would be glad to meet with you to explain our concerns in more detail, if that would be helpful.

Sincerely,

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