Progress Energy

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JAN 27 2009

Serial: HNP-09-011
10 CFR 50.54(f)

U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, DC 20555

SHEARON HARRIS NUCLEAR POWER PLANT, UNIT NO. 1
DOCKET NO. 50-400/LICENSE NO. NPF-63
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (TAC NO. MC4688)

References:
1. Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004
2. Letter from J. Scarola, to the Nuclear Regulatory Commission (Serial: HNP-05-101), "Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors,'" dated September 01, 2005
3. Letter from R. J. Duncan, II, to the Nuclear Regulatory Commission (Serial: HNP-08-015), "Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Bases Accidents at Pressurized-Water Reactors,'" dated February 28, 2008
4. Letter from R. J. Duncan, II, to the Nuclear Regulatory Commission (Serial: HNP-08-037), "Second Supplemental Response to NRC Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design Bases Accidents at Pressurized-Water Reactors,'" dated March 28, 2008
5. Letter from M. Vaaler, Nuclear Regulatory Commission to C. L. Burton, "Shearon Harris Nuclear Power Plant, Unit 1 – Request for Additional Information Regarding Supplemental Response to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors,'" (TAC NO. MC4688) dated September 29, 2008

Ladies and Gentlemen:

NRC Generic Letter (GL) 2004-02 (Reference 1), issued September 13, 2004, requested that addressees perform an evaluation of the emergency core cooling system (ECCS) and containment spray system (CSS) recirculation functions in light of the information provided in the GL and, if

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appropriate, take additional actions to ensure system function.

Carolina Power & Light Company (CP&L) doing business as Progress Energy Carolinas, Inc., provided the requested written response for the Harris Nuclear Plant (HNP) to the NRC in accordance with 10 CFR 50.54(f) on September 01, 2005 (Reference 2). In addition, supplemental responses were provided on February 28, 2008, and March 28, 2008, (References 3 and 4).

On September 29, 2008, the NRC issued a request for additional information (Reference 5), regarding the above submittals. Attachment 1 to this letter provides HNP's responses to the questions.

Attachment 2 contains HNP's regulatory commitment associated with this response.

Please refer any questions regarding this submittal to Mr. Dave Corlett at (919) 362-3137.

I declare under penalty of perjury that the foregoing is true and correct. Executed on
[JAN 27 2009].

Sincerely,

Christopher L Burton

Christopher L. Burton
Vice President
Harris Nuclear Plant

CLB/kms

Attachments:
1. HNP's Response to the Request for Additional Information Regarding Supplemental Response to Generic Letter 2004-02
2. HNP's Regulatory Commitments

cc:
Mr. J. D. Austin, NRC Sr. Resident Inspector, HNP
Ms. M. G. Vaaler, NRC Project Manager, HNP
Mr. L. A. Reyes, NRC Regional Administrator, Region II

SHEARON HARRIS NUCLEAR POWER PLANT, UNIT NO. 1
DOCKET NO. 50-400/LICENSE NO. NPF-63
RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION REGARDING SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02

The emergency core cooling system (ECCS) and the containment spray (CS) recirculation functions for Harris Nuclear Plant (HNP) continue to comply with the requirements listed in the applicable Regulatory Requirements section of Generic Letter (GL) 2004-02 with regard to debris loading conditions. As previously submitted, HNP's Supplemental Response to GL 2004-02 describes the completed corrective actions that ensure this compliance.

NRC Request 1:

The submittal dated February 28, 2008 (Agencywide Documents Access and Management System (ADAMS) Accesssion No. ML080670099), stated that the break selection process was simplified due to the large zones of influence (ZOIs) associated with the target materials. This simplification may be valid for the relatively large ZOIs, but may not be valid for the 4 pipe diameter (4D) ZOI that the licensee used for Min-K [microporous insulation], and the 5D ZOI used for qualified coatings, if care is not taken to maximize the amount of debris created for these smaller ZOIs.

Please verify that the hypothetical breaks were moved systematically to ensure that the amount of debris created was maximized for ZOIs smaller than the entire compartment. This is especially important for the Min-K debris that has been shown to have the potential for a large effect on head loss and has a very small ZOI for the Shearon Harris Nuclear Power Plant, Unit 1 (HNP) evaluation.

HNP Response:

Multiple break locations were considered to determine the bounding break locations that generate the largest amount of insulation debris or that generate the largest potential particulate debris to fibrous debris ratio. The most limiting break that imposes the greatest challenge to the post-accident sump recirculation performance is not necessarily the break that generates the largest amount of debris, but perhaps the break that generates the worst combination of debris amount, debris type and location relative to the sump. Therefore, debris generation in conjunction with pool-transport and debris head-loss calculations determined the most limiting break. Certain break locations that were initially analyzed were not further considered because they generated a lesser debris load and were located close to the selected break locations.

For break locations A-2, B-1, C-1 (bounding Loss of Coolant Accident (LOCA) for each steam generator (SG) compartment A, B, and C), RN-1 (reactor vessel nozzle break), and P-2 (break within the pressurizer cubicle), the total surface area of destroyed qualified coatings within the ZOI was estimated using a plant-specific AutoCAD model of containment developed in support of the debris-transport analysis for the bounding break locations. The AutoCAD model was used to estimate the total surface area of destroyed qualified coatings within a 5D ZOI.

WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings," Revision 0, recommends that a minimum ZOI radius of 4D be used for Design Basis Accident (DBA) qualified/acceptable epoxy coatings for post-accident sump evaluations, based on testing documented in the WCAP. The use of a 4D ZOI for qualified epoxy coatings is acceptable per "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Coatings Evaluation." HNP conservatively uses a ZOI radius of 5D for qualified epoxy coatings.

For the Min-K, the hypothetical break was systematically moved to ensure that the amount of debris created was maximized. The Min-K insulation at HNP is located on six lines within the pressurizer cubicle—three power-operated relief valve (PORV) lines and three safety valve lines. The PORV lines are 3 inches in diameter, and the safety valve lines are 6 inches in diameter. After reviewing the drawings, it was determined that the ZOI for Min-K will only affect the line on which the break location exists. The distance between each of the safety relief valve lines is greater than 2 feet, which is the radius of the ZOI. The same situation exists for the PORV lines. In addition, the safety relief lines are not in close proximity to the PORV lines. Therefore, it was determined that a break on one of the 6 inch safety relief valve lines will generate the largest amount of Min-K. Note that the ZOIs for all other piping breaks, beyond the safety relief valve line and PORV line breaks, do not encompass any of the Min-K.

NRC Request 2:

The licensee stated that the licensing basis break size inside the reactor cavity is 150 square inches. This corresponds to a piping inside diameter (ID) of about 14 inches. The submittal was not clear as to what piping ID provided the basis for the ZOIs. Please provide the piping diameter or break size that is the basis for the ZOIs for each break.

HNP Response:

The limiting breaks for HNP are:

1. Case 1: Reactor Coolant System (RCS) break on the loop B crossover leg at the SG
2. Case 2: RCS break near the reactor vessel nozzle
3. Case 3: Break on a pressurizer safety line

The pipe diameter that is the basis for the ZOIs for Case 1 is the crossover leg pipe inner diameter of 31 inches. The pipe diameter that is the basis for the ZOIs for Case 2 is the hot leg pipe inner diameter of 29 inches. The pipe inner diameter that is the basis for the ZOIs for Case 3 is a pressurizer safety line of 6 inches. Note that the 150 square inch area reported in the Supplemental Response (Reference 3) was not directly used to develop a ZOI. Rather, the area was provided as one of several justifications for establishing 50 percent as the fraction of material destroyed due to an RCS line break at the reactor vessel nozzle.

NRC Request 3:

Please provide details on the assumptions made regarding the size and shape of each ZOI for each break. If the ZOIs are not spherical and based on the piping diameter, provide the basis for the assumptions. Describe how debris generation from a spherical ZOI based on a given piping diameter would compare to the debris generation from a corresponding alternate-shaped ZOI.

HNP Response:

The following ZOI radii were used in the debris-generation calculation:

Debris Species	ZOI radius
Nukon, Thermal-Wrap	17D (D is the pipe inside diameter)
Mirror RMI , Microtherm	28.6D
Min-K	4D
Qualified Coatings	5D
Temp-Mat	11.7D

The shape of each ZOI for each break is spherical. If a robust barrier, such as a concrete wall, is encountered by a break jet, the ZOI created is assumed to have a spherical boundary with the exception of the volume beyond the robust barrier.

NRC Request 4:

The licensee used a ZOI reduction for encapsulated Min-K from 28.6D to 4D based on Continuum Dynamics, Inc. (CDI) testing of Diamond Power reflective metallic insulation (RMI). The test is documented in CDI Report Number 96-06. Considering that the debris generation analysis for encapsulated Min-K diverged from the approved guidance in NEI [Nuclear Energy Institute] 04-07, please provide the details of the testing conducted that justified the ZOI reductions.

The information should include the jacket materials and construction used in the testing, geometries and sizes of the targets and jet nozzle, and materials and construction of the jackets installed in the plant. (e.g. Diamond Power RMI was found to have a ZOI of 28.6D while Transco RMI was found to have a ZOI of 2D. The major difference in construction between the two is that Diamond Power RMI is spot welded and Transco RMI is seam welded.)

Provide information that compares the mechanical configuration and sizes of the test targets and jets, and the potential targets and steam jets in the plant. Evaluate how any differences in jet/target sizing and jet impingement angle affect the ability of the insulation system to resist damage from steam impingement. State whether the CDI testing cited in the submittal bounds the plant Min-K insulation jacketing system design. If not, provide information that compares the plant encapsulation and jacketing system structure with the system that was used in the CDI testing, showing that the CDI testing conservatively or prototypically bounds potential damage to the Min-K insulation system.

HNP Response:

Min-K insulation is installed on six lines within the pressurizer cubicle; three of the lines are for the safety relief valves (SRVs), and the other three lines are for the PORVs. The PORV lines are 3 inches in diameter, and the SRV lines are 6 inches in diameter. The Min-K insulation is fully encapsulated within stainless-steel cassettes. The thickness of the stainless-steel sheeting encapsulating the insulation on the 3 inch lines is 0.025 inches thick, and the thickness of the stainless-steel sheeting encapsulating the insulation on the 6 inch lines is 0.032 inches thick. Walkdown inspections have confirmed that the cassette seams are tightly riveted (i.e., a large number of rivets closely spaced along the seams) and that the individual cassettes are latched and buckled together.

The Air Jet Impingement Testing (AJIT) conducted on Transco RMI and Diamond Power (DPSC) Mirror insulation cassettes with riveted construction indicated that the cassettes were removed from the target piping with the cassette sheaths separated from each other at low impingement pressures (4 psig). For the DPSC tests, the test report states that failure of the latches and buckles caused the separation of the inner and outer sheaths of the cassettes. Additional testing was performed on the DPSC Mirror insulation that was banded to the target piping. The construction of the cassettes was the same as was tested without banding. These tests, performed at jet impingement pressures of 20 psig (test 29-1) and 105 psig (test 29-2), did not generate any RMI debris. During these tests, the cassettes remained on the target pipe, and there was no penetration of the cassettes by the jet. Because the RMI foils are not rigid, the side of the cassette facing the jet-impingement nozzle was flat against the target pipe.

These two tests were conducted on DPSC Mirror insulation with stainless-steel sheeting with a thickness of 0.032 inches. The insulation cassettes were 36 inches in length and were installed on 12 inch nominal pipe size target piping (outer diameter of 12.75 inches). Two bands were mounted 4 inches from each cassette end, and a third band was on the centerline of the cassette under the handles. The jet nozzle was 3 inches in diameter. The maximum test stagnation pressure at the nozzle was 1,118 psig for test 29-1 and 1,120 psig for test 29-2, and the pressure at the surface of the insulation was approximately 20 psig for test 29-1 and 105 psig for test 29-2. The test target was perpendicular to the jet centerline.

One difference between the RMI tested and the Min-K insulation is the compressibility of the two types of insulation. The RMI tested is very compressible because the foils comprise a small portion of the volume within the cassettes. On the other hand, Min-K is a powdery insulation that is not as compressible as RMI and contains fewer voids. It is expected that if Min-K cassettes were subjected to similar jet-impingement loads that the Min-K insulation would transfer much of the jet-impingement load to the piping without causing the cassette to flatten around the piping. A potential concern was whether the Min-K that is compressed by the jet would impose a load on the sides of the cassette that are not facing the jet such that these sides would detach, thereby allowing Min-K to possibly escape from the cassette. To address this concern, bands were installed around all sides of the Min-K cassettes to the greatest extent possible. When it was not possible to band all sides, other reinforcements discussed in this response were used or it was determined that the loads exerted on the un-impinged sides would be resisted by adjoining insulation.

Because the thicknesses of the sheeting of the cassettes on the plant piping is equal to or approximately equal to the thickness of the sheeting of the cassettes used in the DPSC testing, it is not expected that the installed cassettes, with banding, would be compromised at jet-impingement pressures as high as 105 psig. For conservatism, a destruction pressure of 40 psig was credited for the banded Min-K cassettes. According to Table 3-1 of the NRC's Safety Evaluation (SE) of NEI 04-07, a jet impingement pressure of 40 psig corresponds to a ZOI of 4D. Section 3.4.2.2 of the SE states that damage pressures for all material types characterized with air-jet testing should be reduced by 40 percent to account for potentially enhanced debris generation in a two-phase PWR jet. Reducing 105 psig by 40 percent yields 63 psig as the equivalent LOCA jet design pressure. Because this pressure is still greater than 40 psig, the use of 40 psig is conservative.

Bands have been installed around the Min-K cassettes similar to the banding installed on the targets used in the DPSC testing. The design details for the banding on the cassettes is specified as follows:

- The bands shall be fabricated using 16 gauge (0.062 inches thick) 304 stainless steel material (or equivalent) and shall be 2 inches wide (or equivalent). When installation of a 2 inch band is not practical due to interferences, a notched 4 inch band may be used. The notched 4 inch band is acceptable because band failure observed in the testing was due to the failure of the latch and strike assemblies and not of the banding material itself. The notching is such that the band retains a significant tensile strength.
- For the cassettes that are fabricated as boxes around the SRVs and PORVs, the bands should be located on all sides of the cassettes.
- The maximum centerline distance between bands should be approximately 13 inches, and each cassette or cassette assembly shall contain a minimum of two bands. The tested

cassettes were 36 inches long, and two bands were located within 4 inches of the edges of the cassettes. The third band was located along the cassette centerline. Because the tested bands were 2 inches wide, the centerline distance between the bands was 13 inches.

- To secure the bands around the Min-K cassettes, angle iron brackets should be installed at the ends of the bands. A minimum one-fourth inch diameter bolt or threaded rod should be used to connect the brackets installed on the bands. This bolt or threaded rod is much stronger than the strikes and latches used in the testing, as these strikes and latches were fabricated from thin-gauge stainless-steel plate.

Per Revision 1 of the modification package for the installation of the bands, the above criteria have been revised to accommodate field conditions and still provide adequate insulation reinforcement. Revisions to the above criteria include:

- Use of 4 inch wide banding was not practical due to the small surface areas of most insulation assemblies. Only minimal notching was accomplished. One 2 inch wide band was notched leaving 1.5 inches of band. This was considered acceptable because the original notching detail for the 4 inch banding allowed removal of all but 1.5 inches of material. Because the notched area is the weak point, the width of wider areas of the band does not add significant strength.
- On some of the cylindrical sections of insulation, two bolt-type connectors were riveted directly to the insulation sheeting instead of using bands. This is acceptable because the entire outer casing of the cassette is being treated as a band. With the bolted connectors in place, the insulation will remain on the pipe and not be destroyed, and there will be no mechanism for tearing the outer casing apart and exposing the Min-K.
- In some cases, due to the geometry of the cassettes, corner brackets were added for additional reinforcement. Based on the test report, the failure mode for Mirror insulation in all cases was failure of the corner tabs.

The requirement to maintain a maximum of 13 inches between bands was adhered to as much as possible. In some cases, the 13 inches is exceeded due to interferences. These locations have been inspected and accepted based on the presence of sufficiently robust banding, connectors, and corner reinforcements securing all sides of the assembly.

The AJIT report states that "(t)ests were conducted in the configuration determined to be most conservative with respect to debris generation, based upon previous test results." The report also states that "tests of RMI cassettes were typically conducted with the latches and strikes in plane with the exhaust nozzle. This allowed determination of the minimum pressure at an insulation surface where the most damage could occur to that insulation." It can be deduced from these statements that a jet from a nearby broken pipe will produce the most damage to the insulation when the jet is aimed directly at, and in plane with, a joint between two sections of insulation.

Therefore, jets originating outside of the 4D ZOI will not result in unacceptable damage to the insulation, regardless of the angle of impact. While the credited testing in the report was conducted on insulation on round horizontal piping in sections 36 inches long, the report does not state that such orientation or insulation geometry is a critical attribute. The failures were caused by broken latches and failure of rivets.

The banding applied to the HNP insulation resolves both concerns because the banding and associated joining bolts are very robust, and the rivets used to attach material to the insulation jacketing are also very robust. Instead of using the Camloc latches and strikes used in the testing, all banding is joined by 2 one-fourth inch diameter bolts. In some cases, ends of banding are attached to the outer jacket of the insulation using two or more one-fourth inch diameter stainless-steel rivets. Both of these methods of securing banding have strength comparable to or superior to the Camloc latches and strikes.

As mentioned above, the jet nozzle used in the testing was 3 inches in diameter, which is similar in size to the 3 inch and 6 inch diameter lines on which the Min-K insulation is installed.

It is therefore concluded that the AJIT results, specifically tests 29-1 and 29-2, are applicable to the HNP insulation with the banding installed.

NRC Request 5:

The supplemental response dated March 28, 2008 (ADAMS Accession No. ML080940495), provides four-category debris size distributions for low-density fiberglass debris in 3 sub-regions of the 17D ZOI. However, a single integrated size distribution for the entire 17D ZOI (i.e., one four-category size distribution created by summing the individual contributions from all three sub-regions) was not provided for the analyzed breaks. Without knowing the integrated debris size distribution over the entire 17D ZOI, the staff is unable to verify whether the transport results and head loss testing source term are reasonably representative of the expected plant values. Therefore, please provide the integrated debris size distribution for the 17D ZOI for the low-density fiberglass insulation for the analyzed breaks.

HNP Response:

The crossover-line break is the only one of the three limiting breaks that results in the destruction of low-density fiberglass insulation. The integrated size distribution for the entire 17D ZOI for the low-density fiberglass insulation for the limiting crossover leg at the SG nozzle break is provided in the following table:

Insulation type	Size	Debris Generated (ft^3)
Nukon	Fines (Individual Fibers)	8.38
	Small Pieces (<6" on a Side)	32.41
	Large Pieces (>6" on a Side)	5.28
	Intact Blankets	5.64
Thermal-Wrap	Fines (Individual Fibers)	68.08
	Small Pieces (<6" on a Side)	241.7
	Large Pieces (>6" on a Side)	117.84
	Intact Blankets	125.86

<u>NRC Request 6:</u>

Since the time of the two pilot audits for Generic Safety Issue (GSI)-191 (Crystal River 3 and Fort Calhoun), the staff has had unresolved concerns associated with the use of turbulent kinetic energy (TKE) metrics for justifying the settling of fine debris, including the following: (1) the lack of experimental benchmarking of analytically derived TKE metrics; (2) uncertainties in the predictive capabilities of TKE models in computational fluid dynamics (CFD) codes, particularly at the low TKE levels necessary to suspend individual fibers and 10-micron particulate; (3) the analytical prediction of settling velocities in quiescent water due to the specification of shape factors and drag coefficients for irregularly shaped debris; and (4) the theoretical correlation of the terminal settling velocity to turbulent kinetic energy that underlies the Alion Science and Technology Corporation (Alion) methodology for fine debris settling.

A justification for the settling of fine debris is provided on page A1-18 of the supplemental response, but this discussion does not fully address the staff's concerns above. Please describe the extent to which settling of fines was credited in the transport analysis, the metrics used, and, to justify any settling credit taken, please also address the four numbered points above, many of *which were documented in previous audit reports for other licensees who used a similar methodology.*

HNP Response:

The HNP debris-transport analysis assumes that all fine debris, with the exception of fiberglass fines, has a recirculation transport fraction of 100 percent. Therefore, this RAI is applicable only to the transport of fiberglass fines.

The limiting break location with respect to the quantity of fiberglass debris generated and transported would produce a total of 606 cubic feet of fiberglass debris (52 cubic feet of Nukon and 554 cubic feet of Thermal-Wrap). Of this 606 cubic feet of fiberglass debris generated, 76 cubic feet is classified as fines. If the recirculation transport fraction for the fines is increased to 100 percent, the overall transport fraction of the fines would increase from 88 percent to 94 percent, resulting in an increase of only 4.6 cubic feet of fiberglass debris at the strainer. Similarly, the overall transport fraction of the latent fiber fines would increase from 73 percent to 77 percent, resulting in an increase of only 0.51 cubic feet of latent fiber debris at the strainer.

It is acknowledged that there is uncertainty in both the TKE metrics and CFD code predictions of low TKE levels. However, there are several conservatisms in the debris-transport analysis that offset the uncertainty of the small portion of individual fibers setting in the recirculation pool. For example, during the blowdown phase, some of the fiberglass fines and small pieces would be impinged on wall and structures as well as crevices where it is likely that this fiberglass would not ever reach the recirculation pool. Also, a portion of the fiberglass fines blown to upper containment may not be exposed to containment spray and would not be washed down. Some of the fiberglass fines that reach the recirculation pool would agglomerate with other fines or be trapped by clumps and larger pieces of fiberglass, reducing the transport of the fines to the strainer. Other fiberglass fines would be captured in eddies where the debris could circulate with the flow indefinitely. Each one of these phenomena could result in a reduction of the quantity of fiberglass debris that is transported by a few percent. Although the individual impact may be small, the cumulative effect of these conservatisms outweighs the difference between taking credit for fiberglass fines settling in stagnant regions of the recirculation pool versus assuming 100 percent recirculation transport.

NRC Request 7:

The staff questions the conservatism of assuming that 100 percent of latent debris is on the containment pool floor during pool fill up, such that 15 percent of this debris is transported directly to inactive pool volumes. In actuality, latent debris will be distributed through containment, and much of it would seemingly be washed down following the initial filling of the *containment pool. For this reason, taking credit for 15 percent of latent debris being washed into inactive pool volumes appears non-conservative. Please provide justification for this position.*

HNP Response:

The debris-generation and debris-transport calculations are based on an assumed mass of latent debris of 200 lbm, which is consistent with the guidance in NEI 04-07. Since the calculations were developed, a latent-debris walkdown was performed. The walkdown results indicate that on a unit-area basis of the locations, the locations with the highest debris density are at the lowest elevation. There would be some latent debris that could be washed down from the upper elevations, but those areas were determined to have a lower debris density than the lowest elevation. Thus, the basis for assuming that 100 percent of the 200 lbm on the containment floor is still representative.

The walkdown estimated that 29.3 lbm of latent debris is on horizontal surfaces. This value is conservative as it uses the highest debris density instead of an averaged value. Another conservatism was introduced by tripling the estimated mass of latent debris to a value of 87.9 lbm on horizontal surfaces. Consistent with the SER on NEI 04-07, 30 lbm of latent debris on vertical surfaces was assumed, which yielded a total mass of 117.9 lbm of latent debris. This conservative mass of latent debris is significantly less than the assumed mass of 200 lbm such that it is reasonable to conclude that the mass of latent debris that would be transported to the sump following a LOCA is bounded by the debris-generation and debris-transport calculations.

NRC Request 8:

The staff considers the assumption that small pieces of fibrous debris are held up on gratings in upper containment during washdown to be inadequately supported by the NRC Drywell Debris Transport Study (NUREG/CR-6369) data cited by the licensee. The 40 to 50 percent retention cited by the licensee from NUREG/CR-6369 was for a 30-minute test. The staff's conclusion from this testing, which is stated in NUREG/CR-6369, was that no credit should be allowed for retention based on this test data. Therefore, please provide an adequate technical basis to support the assumption of 40 to 50 percent retention of small fibrous debris pieces on containment gratings.

HNP Response:

The HNP debris-transport calculation uses test data from the drywell debris transport study (NUREG/CR-6369) to take credit for small pieces of fiberglass being held up on gratings. In the NUREG/CR-6369 testing, 1.5 inch pieces of fiberglass, obtained directly from air-jet testing, were placed on 1 inch x 4 inch grating and subjected to a simulated containment spray flow rate per area of 5 gpm/ft^2. The results of this testing showed a reduction in fiberglass mass on the grating of between 38 percent and 47 percent.

The HNP grating consists of 1-1/4 inch x three-sixteenths inch bearing bars spaced on 1-3/16 inch centers and crossbars spaced not more than 4 inches on centers, which is very similar to that used in the testing. The HNP containment spray flow rate per area is 0.281 gpm/ft^2, based on the maximum two-train containment spray flow rate and the cross-sectional area of the containment building. This value of spray flow rate per unit area is an order of magnitude less than the value of 5 gpm/ft^2 that was used in the testing. Additionally, the small pieces of fibrous debris considered in the HNP analyses are less than 6 inches on a side, whereas the small pieces of fibrous debris used in the testing were 1.5 inches on a side.

The NUREG/CR-6369 test data show that medium pieces of fibrous debris (about 6" x 4"), produced by both air-jet testing and by cutting intact insulation blankets, have a washdown fraction of 2 percent to 33 percent for the testing involving simulated containment spray flow. NUREG/CR-6369 states that a transport fraction of 0.5 appears reasonable for medium pieces of fiberglass debris subjected to containment spray flow.

It is possible that some additional washdown could occur after thirty minutes. However, NUREG/CR-6369 states that based on visual observation of test E-13, the majority of the washdown occurred within the first fifteen minutes. Given this observation, HNP does not think it likely that a significantly larger quantity of fibrous debris would have been washed down if the test were run longer than thirty minutes. To account for some uncertainty in the testing, the observed fractions of 38 percent to 47 percent (1.5 inch pieces) and 2 percent to 33 percent (6" x 4" pieces) were conservatively rounded up to 50 percent. The erosion of fiberglass debris that is retained on grating by containment spray flow is addressed separately in the debris-transport calculation and is included as an additional transport term in the logic trees.

The debris-transport analysis conservatively assumes that all fibrous debris that is transported to the operating deck is washed down to lower containment, with the exception of any small-piece debris held up on gratings. Washdown to lower containment is via the refueling canal drain, the openings in the operating deck above the RCS loops, and the annulus. However, curbing around the refueling cavity and the troughs for the manipulator crane rails will preclude transport of the fibrous debris to the refueling canal. Furthermore, the fluid velocity on the operating deck is not sufficient to transport the small pieces of fiber to the edges of the operating deck.

The models used in NUREG/CR-6762, Volume 4, were designed to identify spaces and surfaces where insulation debris would not likely be washed away by sprays or drainage flow (e.g., an area that is not affected by sprays or that has too little drainage flow to transport debris). Based on these models, the NUREG concluded that washdown of up to 75 percent of the debris deposited on containment surfaces cannot be ruled out. The NUREG focused on sequestered areas as opposed to grating hold-up. The NUREG/CR-6369, Volume 2, Table 4-3 transport factors (38 to 47 percent for small pieces and 2 to 33 percent for medium pieces) were derived from testing where essentially all debris was exposed to spray flow. In other words, the transport factors were based on the underlying assumption that debris blown to the upper containment was exposed to spray flow. This is a fundamental difference between NUREG/CR-6762, Volume 4 and NUREG/CR-6369, Volume 3 in the approach used to evaluate washdown transport. The 25 percent "sheltering" fraction from NUREG/CR-6762 is generically applicable to the small-piece debris blown to the HNP upper containment. However, this conservatism was not credited in the HNP washdown transport analysis.

For these reasons, crediting a 50 percent grating hold-up fraction is considered reasonable and conservative.

NRC Request 9:

The licensee credited NUREG/CR-6369 results for the trapping of fibrous debris on gratings during blowdown. The staff noted that a number of tests were performed for NUREG/CR-6369, and that numerous tests showed much less capture than the value assumed by the licensee. The staff also noted that many of the NUREG/CR-6369 tests with larger capture fractions appeared to include debris fragments in the "6+" size category, which is larger than a standard floor grating opening. Therefore, the staff requests that the licensee identify the specific tests from NUREG/CR-6369 used to credit trapping of fibrous debris during blowdown and justify their prototypicality to HNP post-loss of coolant accident (LOCA) conditions.

HNP Response:

The blowdown capture fractions used in the HNP debris-transport calculation were taken from Table E-1 of NUREG/CR-6369, Volume 2, which is reproduced below. Table E-1 lists average fractions of debris captured by each test structural component.

Structure Type	Capture Fraction Small Debris	Capture Fraction Large Debris
I-beams and pipes arranged to prototypical congestion over a debris path length to 20 ft	9%	~0%
Gratings V-shaped grating (at an angle with flow) Other gratings (normal to bulk flow)	 28% 24%	 100%
90° bend in the flow	17%	(None tested)
Mark I vent entrance	< 10%	(None tested)
Mark II vent entrance	15%	(None tested)

As shown in this table, the capture fraction for small fiberglass debris from miscellaneous structures such as I-beams and pipes is 9 percent. This was rounded to 10 percent in the debris-transport calculation. The capture fraction for small fiberglass debris from grating would be either 28 percent if the blowdown flow approaches the grating at an angle or 24 percent if the blowdown flow is normal to the grating. A capture fraction of 25 percent was used for grating in the debris-transport calculation. The capture fraction for small fiberglass debris from 90° changes in the flow direction is 17 percent. Because the majority of debris blown toward upper containment at HNP would not have to pass through 90° turns but could make partial flow turns, a capture fraction of 5 percent was used in the debris-transport calculation. These individual capture fractions are consistent with the analysis performed for the pilot plant in Appendix VI of the SE on NEI 04-07.

Note that if less debris is captured by the grating, the blowdown transport fraction of small fiberglass debris to upper containment would be increased. Because a portion of this debris would be retained in upper containment, the overall transport of fiberglass to the strainer would be decreased. In the debris-transport analysis, all of the debris captured in lower containment during the blowdown phase is conservatively assumed to reach the containment pool. Also, Appendix VI of the SE on NEI 04-07 states that "(i)t is likely conservative to capture more debris within the SG than to transport the debris throughout the containment because washdown within the SG should be relatively greater than some other areas of the containment and because debris washed off the SG structures can go directly to the sump pool."

NRC Request 10:

Erosion testing performed at a relatively low velocity of 0.12 feet per second (ft/sec) was used to justify an erosion fraction of 10 percent for small and unjacketed large pieces of low-density fiberglass. The licensee provided a basis for applying this test data to the HNP post-LOCA conditions, but the staff considered the basis lacking in three respects.

First, the licensee stated that the HNP "bulk pool velocity" was of the order of magnitude of 0.12 ft/sec, but it is questionable to the staff whether this apparently averaged velocity value adequately represents erosion conditions throughout the containment pool. In particular, based on the debris transport results presented by the licensee, it appears that a significant part of the containment pool at HNP could experience flows greater than the 0.12 ft/sec velocity tested.

Second, since 0.12 ft/sec is an incipient tumbling velocity for shreds of fiberglass, most large and small pieces of fiberglass would actually require a larger velocity to transport. Thus, erosion of settled pieces of fiberglass would actually occur at velocities significantly larger than 0.12 ft/sec, particularly for large pieces.

Third, there is uncertainty because the testing was likely performed in tap water, whereas higher-pH containment pool solutions could dissolve binder material and aid in the erosion process. Please provide additional justification that supports the application of the fibrous debris erosion testing results to the HNP post-LOCA conditions. In doing so, please address the three issues stated above.

HNP Response:

Erosion testing was performed both at an average flow velocity of 0.12 ft/sec for small-sample pieces (1" x 1" x 1" pieces) and at an average flow velocity of 0.37 ft/sec for large-sample pieces (6" x 3" x 1" pieces). Test results demonstrate that an erosion rate of 10 percent over a thirty-day period is appropriate for both large and small pieces of fiber. The debris-transport analysis assumes that all small pieces of fiber located throughout the containment pool at an average flow velocity of 0.12 ft/sec or greater and that all large pieces of fiber located throughout the containment pool at an average flow velocity of 0.37 ft/sec or greater transport to the sump strainer. Because the incipient tumbling velocity is the velocity at which the debris would start moving, this velocity bounds the greatest velocity that a piece of insulation in the containment pool would experience without being transported to the sump strainer. Therefore, it is considered the velocity that would produce the most insulation fines that would travel to the sump strainer while the piece of insulation itself would remain stationary in the pool.

The erosion tests were conducted at room temperature in tap water. Prior to the start of each test, each sample was boiled in tap water for at least ten minutes to remove the binder. The increased post-LOCA water temperatures would have little effect on the flow erosion of fiberglass with respect to differences in the density and viscosity of the water. The neutral pH of the water used in the testing would also have little effect on the flow erosion mechanism, as the testing determined the amount of fiberglass mechanically removed by the water flowing past stationary insulation samples.

NRC Request 11:

In Table 3b.4 of the supplemental response, the licensee calculated that a total of roughly 375 square feet (ft^2) of foreign material debris would become post-LOCA debris available to collect on the strainer. Yet only 100 ft^2 of sacrificial area was allotted to accommodate this debris. The staff guidance allows the use of 75 percent of the total area to account for possible overlap of debris. Therefore, it would appear that approximately 280 ft^2 should have been subtracted from the total strainer area prior to scaling. Please provide the basis for crediting a reduction in debris transport of this magnitude.

HNP Response:

There are four sources of miscellaneous debris: insulation labels, HVAC labels, temporary modification tags, and tape on the elevator ramp. The tape on the elevator ramp is approximately two square feet in area and would be submerged following a LOCA. This tape is conservatively assumed to transport to the sump. Similarly, the temporary modification tags are assumed be 0.62 square feet in area and are conservatively assumed to transport to the sump.

The total area of the insulation labels is estimated to be 343.8 square feet, and the total area of the HVAC labels is estimated to be 29.2 square feet. Similar labels sink in water, and the insulation labels are of similar size to some of the postulated RMI debris. Testing described in NUREG/CR-6772 determined that at a fluid velocity of 1 ft/s, neither the one-half inch pieces nor the 2 inch pieces of RMI were transported over a 6 inch high curb. The curbs surrounding the HNP sumps are 18 inches tall, and the average water velocity over the top of the curb during recirculation is less than 0.24 feet per second. The total volume of the insulation labels and the HVAC labels is estimated to be 5.6 cubic feet. There is a total of 22.6 cubic feet of margin in the amount of debris the curbs could hold up. Thus, it is not expected that any of the labels would be transported to the sump screens. However, for conservatism, it is assumed that 10 percent of these labels would transport to the screens, for a total area of 34.4 square feet of insulation labels and 2.92 square feet of HVAC labels assumed to transport to the sump screen.

The total area of the tape on the elevator ramp, temporary modification tags, insulation labels, and HVAC labels that are assumed to be transported to the sump screen is 40 square feet, neglecting any overlapping. A plant procedure allows 40 square feet of floatable items to be carried into containment during containment entries. Assuming all of these floatable items are transported to the sumps, there would be a total of 80 square feet of screen area covered with such debris. This area is less than the 100 square feet of strainer area allotted for miscellaneous debris.

NRC Request 12:

Please clarify which CFD cases were used for each of the three scenarios analyzed in the debris transport discussion. In particular, the case of the reactor nozzle break did not appear to be analyzed explicitly. Please justify the applicability of the analyzed CFD cases to the reactor nozzle break.

HNP Response:

Three separate CFD cases were run to investigate the difference in recirculation transport for a break close to the sump versus a break far from the sump as well as the difference in transport given the maximum flow rates associated with a single failure of a train and a single failure of an RHR pump. Case 1 considers a break in the A RCS piping with a single failure of the A train (i.e., the B train sump is operating); Case 2 considers a break in the B RCS piping with a single failure of the A train; and Case 3 considers a break in the worst-case location with a single failure of the A RHR pump. Note that full-train operation of both sumps is not a limiting case because the debris would be distributed across both sump screens rather than across a single sump screen, and the flow rate through each sump would be lower than the flow rate through the sump with the operating RHR pump given a single failure of the RHR pump associated with the other sump. CFD Case 1 is the limiting CFD case, as it yields the worst-case recirculation transport fractions. This case was used in evaluating all three break scenarios.

Use of CFD Case 1 is conservative for the reactor cavity break case because much of the kinetic energy from a break inside the reactor cavity would be dissipated before reaching the main containment floor. Use of CFD Case 1 is also conservative for the pressurizer cubicle break case because after equilibrium is reached, the flow rates through the smaller lines in the pressurizer cubicle would likely be lower than the flow rates through the large primary loop piping.

NRC Request 13:

The Min-K specific head loss test that incorporated the bypass eliminator mesh resulted in an unacceptable head loss (9.37 ft) and was considered non-representative of the plant because the bypass eliminator mesh was not installed in the final HNP strainer design. The licensee's supplemental response essentially concludes that the removal of the bypass eliminator mesh is solely responsible for the reduction in head loss (to 3.57 ft) observed in the subsequent head loss test, according to the information provided by the licensee, ultimately demonstrated a very small passing margin of 0.12 ft.

However, the staff has seen degrees of variation in head loss results on the order of feet when identical head loss tests have been repeated. The staff therefore believes that the difference between the two test results cited above, potentially due to or due in part to the presence of the bypass eliminator mesh, could also be in part due to random variation in head loss testing results.

Please provide the basis for (1) attributing the lower head loss associated with the test without bypass eliminators solely to the removal of the mesh and (2) the position that the expected variation associated with a repeat test performed for the HNP strainer design without bypass eliminators could not exceed the small demonstrated margin available for the residual heat removal (RHR) pumps of 0.12 ft.

HNP Response:

Test #4 (Min-K test without bypass eliminator mesh) was conducted identically to Test #3 (Min-K test with bypass eliminator mesh). Test #4 was conducted with the exact same debris quantities used for Test #3, and the same test procedures were followed. The purpose of not utilizing the debris bypass eliminator was to determine whether or not there is a significant difference in head loss from a test that utilizes the bypass eliminator mesh and one that does not. Observing the representation of the test data in Figure 13-1 and Figure 13-2, the formation of the debris bed following the addition of the non-chemical debris and the first portion of the chemical precipitates in Test #4 closely matched that which was observed in Test #3. The same initial steep increase, then a slight decrease for a short period, followed by a gradual increase over many hours until the head loss eventually levels off and remains constant, was observed in both tests. The obvious difference between the two tests (Tests #3 and #4) is the resultant head loss. Test #4 results are considerably less (by more than 50 percent) than the Test #3 results. Also, as can be seen from the Figure 13-1 and Figure 13-2, the turbidity level is significantly higher for Test #4. The low turbidity levels for Test #3 indicate a fully covered screen capable of filtering particulate and chemical precipitate debris. The high turbidity levels for Test #4 indicate that there is insufficient fibrous debris to cover the strainer and open area is available for particulate debris to circulate through. The addition of each batch of chemical precipitate does not produce a large increase in head loss with each batch which indicates that there is available open area for precipitate to pass through the screen.

These significant differences in bed formation (fully covered screen vs. open screen area) are attributed to the contribution of the bypass eliminator mesh. The bypass eliminator mesh both affects the formation of the debris bed across the strainer and also the formation of a debris bed across the bypass eliminator mesh itself. A review of test photographs shows that the Test #3 debris bed is a very thin, uniform, dense debris bed. Also, the majority of the bypass eliminator mesh is also covered with debris. The Test #4 debris bed is a much thicker, less uniform debris bed, as a result of none of the debris being captured by the bypass eliminator mesh.

Therefore, the turbidity test data and the post-test debris bed photographs provide evidence that the lower head loss associated with the test without bypass eliminator mesh can be attributed to the removal of this mesh. Additionally, non-chemical effects debris testing using the Microtherm debris mixture was performed twice. The initial test yielded a head loss of 0.39 feet, and the confirmatory test resulted in a head loss of 0.48 feet. The difference between these head loss values is less than 0.1 feet, which indicates that test procedures and practices produce satisfactory repeatability of results. Because Min-K is fabricated from the same constituents as Microtherm and because the same test procedures and practices were employed, it is expected that Min-K testing would also yield repeatable results.

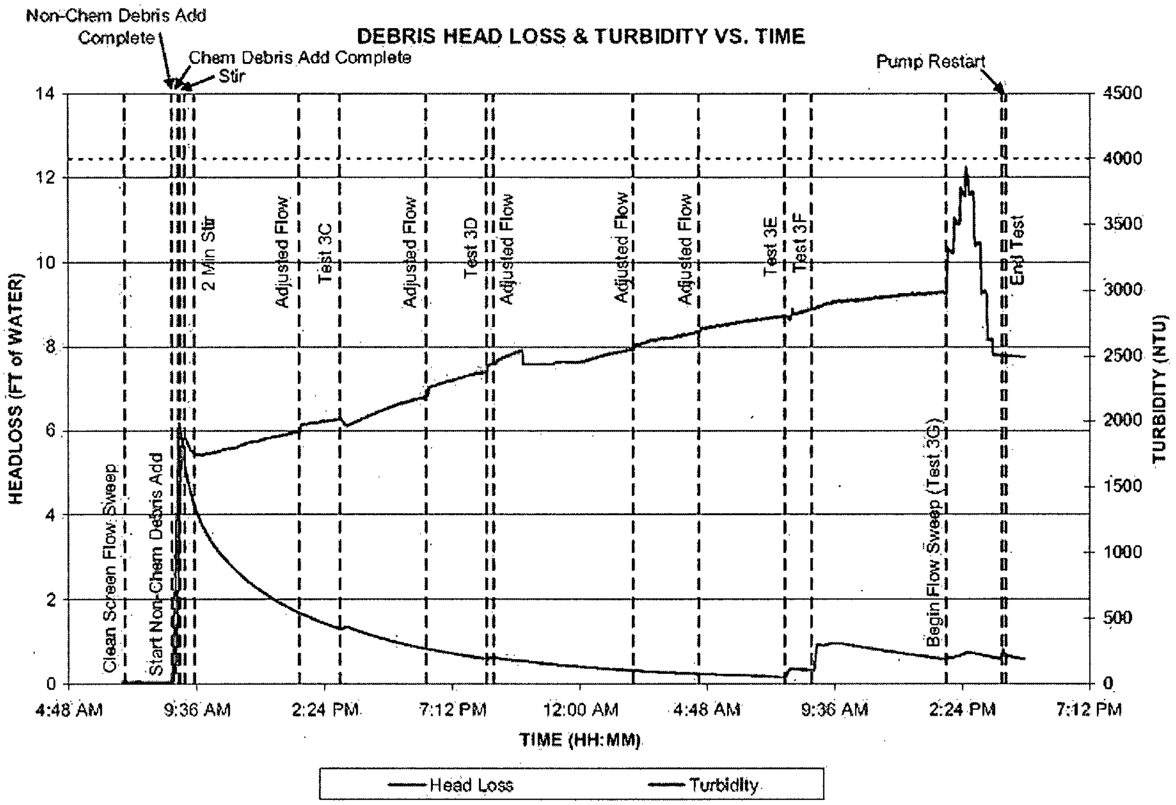

Figure 13-1: Test #3 Chemical Effects Head Loss & Turbidity vs. Time

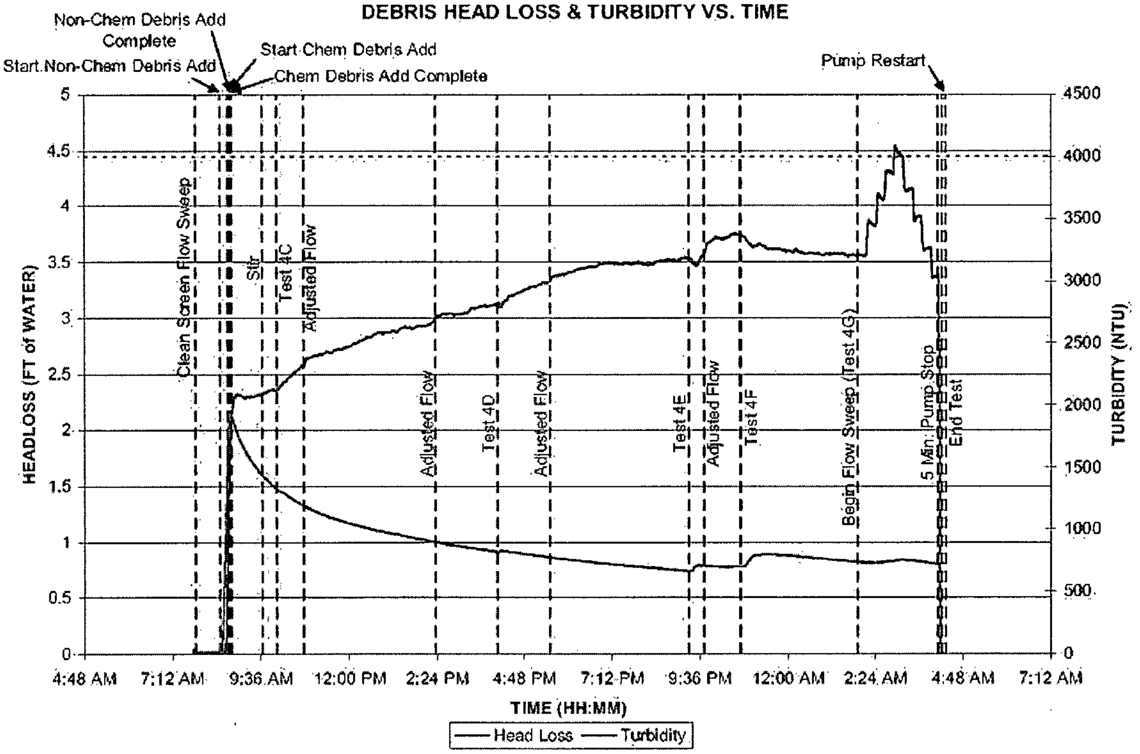

Figure 13-2: Test #4 Chemical Effects Head Loss & Turbidity vs. Time

With respect to the 0.12 feet of residual net positive suction head (NPSH) margin reported in the RAI, the following discussion demonstrates that the residual NPSH margin is in fact significantly more substantial. Vendor curves for the two RHR pumps show that required NPSH is 19 feet at 4,500 gpm and 17 ft at 4,000 gpm. The RHR pump NPSH analysis conservatively uses 4,500 gpm, as this is RHR pump runout flow. The Westinghouse-provided value for recirculation flow during a design-basis LBLOCA is 3,891 gpm. Thus, there is a minimum of two additional feet of NPSH margin. The break that generates Min-K debris is at the top of the pressurizer cubicle, and the largest line that could generate the Min-K debris is nominally six inches in diameter. The RHR pump flow rate for a six inch line break would be substantially less than for a design-basis LOCA. Thus, this break would have even more additional NPSH margin.

Inherent in the standard calculational methodology used to determine NPSH is a conservatism from not crediting the presence of air in containment prior to the accident. The standard methodology assumes the containment pressure is at the saturation pressure corresponding to the sump water temperature. A more realistic, yet still conservative, approach is identified in NEI 04-07, section 6.4.7.1, based on the law of partial pressures. Section 6.4.7.1 states that it is reasonable to assume that the total pressure in containment is the sum of the partial pressure of water vapor corresponding to the sump saturation pressure and the partial pressure of the dry air, which remains constant at the pre-accident value. The partial pressure of dry air prior to the event is to be calculated assuming 100 percent relative humidity at the maximum containment temperature and minimum containment pressure allowed during normal operation. The recognition of the pre-event air pressure acknowledges the thermal-hydraulic condition of containment prior to the event without crediting containment overpressure based on the accident scenarios.

Based on a containment temperature of 130°F (120°F is the maximum allowed by Technical Specifications) and a containment pressure of -1.0 inches water gage (the minimum allowed by Technical Specifications), the minimum dry air partial pressure prior to the event is 12.4 psia. Following the accident, as the containment atmosphere increases in temperature, the partial pressure of air will also increase. The air volume is also compressed as it is displaced by the water spilled and injected into containment following the accident. The resulting increase in the partial pressure of air because of the temperature increase and volume decrease is conservatively neglected.

Another conservative assessment can be made by assuming the design minimum containment air pressure of -2 psig (12.7 psia) and again assuming the containment temperature is 130°F with 100 percent relative humidity. The minimum dry air partial pressure in this case is 10.4 psia.

Conservatively assuming a sump water temperature of 32°F, the density of the sump water is 62.4 lb/ft^3 or 0.43 psi/ft, and the minimum partial pressure of air represents a minimum hydrostatic head of 24 feet. An additional minimum margin of 24 feet obtained by crediting the minimum partial pressure of air provides substantial additional margin to the RHR pump design residual NPSH margin of 0.12 feet.

The two conservatisms described here provide a substantial amount of NPSH margin such that any reasonably expected variation in the head loss through the Min-K debris bed would be more than offset.

NRC Request 14:

The staff has questions regarding the repeatability of the Alion testing based on the results of HNP test cases using Min-K and Microtherm [microporous insulation]. Specifically, given that Min-K and Microtherm are composed of essentially the same base materials (silicon dioxide and titanium dioxide), and given that the amounts of Min-K and Microtherm in the material-specific testing were close to the same (11.6 cubic feet (ft^3) and 12.1 ft^3, respectively), please provide a basis for why these two similar materials had significantly different head loss results in the tests with the bypass eliminator mesh installed. Although the final HNP strainer configuration does *not contain a bypass eliminator mesh, this observation demonstrates the potential for a lack of repeatability in head loss test results.*

HNP Response:

Although Min-K and Microtherm are both composed of the same constituents (fiber, fumed silica, and titanium dioxide), the percentage of each constituent in each insulation material is sufficiently different such that differences in head loss test results between the two materials would be expected. The tables below show the material properties of both Min-K and Microtherm. The two materials differ significantly in the percentage of fiber. This large difference in fiber composition can easily affect the head loss, and the two materials cannot be directly compared in terms of head loss test results.

Microtherm Properties

Debris Type	Percentage Of Total Insulation	Particle Density (lb/ft^3)	Characteristic Size (μm)
Fiber	3 %	165.0	6
Fumed Silica (SiO_2)	58 %	137.0	Varies, centered at 20
Titanium Dioxide (TiO_2)	39 %	262.0	2.5

Min-K Properties

Debris Type	Percentage Of Total Insulation	Particle Density (lb/ft^3)	Characteristic Size (μm)
Fiber	20 %	165.0	Not supplied
Fumed Silica (SiO_2)	65 %	137.0	Varies, centered at 20
Titanium Dioxide (TiO_2)	15 %	262.0	2.5-10

NRC Request 15:

Please provide the fibrous debris size distribution used in testing and compare it to the size distribution predicted by the transport evaluation.

HNP Response:

Dry fibrous debris was cut into twelve inch pieces, then shredded with a shredder and inspected to verify that the debris produced fell in the size Class 1 through 4 of NUREG/CR-6808, Table 3-2. The size classes reported in NUREG/CR-6224, Table B-3, are identical to those reported in NUREG/CR-6808. It is noted that neither of these NUREG reports specify the percentage of debris included in each class. NEI 04-07, Section 3.4.3.3.1, defines "small fines" as debris composed of Classes 1 through 6 of NUREG/CR-6224. Classes 5 and 6 are larger than Classes 1 through 4. Therefore, the HNP fiber was verified to be generally finer than that required by the NEI 04-07 baseline methodology. Fibers were observed to exist in a range of sizes from single individual fibers to small (approximately <1 inch) tufts of fiber before additional processing. Fiber was observed to be substantially smaller than the category defined in NEI 04-07 as "large pieces." The category of "small fines" as described in NEI 04-07 could be applied to the fiber used in the HNP testing based solely on the observed condition of the fiber at the end of the dry processing steps. As discussed below, additional mixing of the fiber with electric paint mixers, combined with the method used to introduce the debris into the test tank, breaks the fiber down further.

After these initial characteristics were met, the shredded fiber was weighed in the desired quantities. The debris was then boiled for at least five minutes to remove the binder and ensure that the fiber would not float. After boiling, the debris was vigorously mixed with water in a confined volume with an electric paint mixer to further break up debris clumps. The paint mixer was typically applied again immediately before each batch of debris was added to the test tank. After mixing, the debris was poured into the test tank in the front corner such that the tank inlet flow readily agitated the debris. As noted in testing documented in NUREG/CR-6808, Section 5.2.6, insulation debris undergoes additional fragmentation producing additional fine debris that remained suspended even at low levels of pool turbulence when it was subjected to flow agitation associated with the inlet flow into the pool. The resulting fines were deemed to be readily transportable and appropriate for testing.

The as-shredded debris, before further disintegration from boiling, mechanical stirring, and agitation from turbulence in the test tank, has an expected terminal settling velocity of 0.13 feet per second or less. The average pool velocity is 0.16 feet per second, indicating that the debris used in head-loss testing is readily transportable to the sump and is typical of what would be expected to transport to the screens.

Although NEI 04-07 only specifies two categories for a baseline analysis, the HNP debris-generation and debris-transport evaluations are based on a refined four-category debris-size distribution: fines, small pieces (<6 inches on a side), large pieces (>6 inches on a side), and intact blankets. As discussed above, fiber debris was prepared to satisfy size Classes 1 through 4 of NUREG/CR-6808. Classes 1 through 4 are equivalent to fines and small pieces identified in the HNP debris-generation calculation. Therefore, the HNP fiber used during testing was generally finer (i.e., did not include any large pieces or intact blankets) than assumed in the debris-generation analysis. However, the distribution between the two sizes used (fines and small pieces) was not explicitly determined during testing.

The crossover leg break is the only analyzed break that results in the destruction of a significant amount of fibrous debris. The integrated debris size distribution of the debris at the sump for the fibrous insulation and latent fiber quantities for the limiting crossover leg at the SG nozzle break, a break at the hot-leg nozzle, and a break at the top of the pressurizer cubicle are provided in the following tables. Latent fiber is typically considered to be fines.

Table 1: Fibrous Debris Size Distribution for a Crossover-Leg Break

Debris Size	Debris Quantity at Sump	
Fines	67 ft^3	38%
Small Pieces (<6")	77 ft^3	43%
Large Pieces (>6")	22 ft^3	12%
Intact Pieces (>6")	12 ft^3	7%
Total	178 ft^3	
Latent Fiber	22 lb (approx. 9 ft^3)	

Table 2: Fibrous Debris Size Distribution for a Hot-leg Nozzle Break (Microtherm)

Debris Size	Debris Quantity at Sump	
Fines	0.22 ft^3	46%
Small Pieces (<6")	0.26 ft^3	54%
Total	0.48 ft^3	
Latent Fiber	27 lb (approx. 11 ft^3)	

Table 3: Fibrous Debris Size Distribution for a Break at the Top of the Pressurizer Cubicle (Min-K)

Debris Size	Debris Quantity at Sump
Latent Fiber	22 lb (approx. 9 ft^3)

NRC Request 16:

Please provide details of the debris addition procedures used. Please include a description of fibrous concentration during debris addition and the method of adding fibrous debris to the test tank. Please provide verification that the debris introduction process did not result in non-prototypical settling or agglomeration of debris.

HNP Response:

For all tests, the fiber and particulate were mixed together in 5 gallon buckets using a paint mixer attached to an electric drill until a homogeneous slurry was formed. The paint mixer was typically applied again immediately before each batch of debris was added to the test tank.

The complete contents of the buckets were then added to the test tank to ensure no loss of fine debris. Typically, the material concentration was approximately one to three pounds of test material per 5 gallon bucket based on Alion standard practice. The slurry was maintained at a low enough debris concentration to ensure proper mixing of all the materials in the bucket. For the chemical-effects tests, the chemical precipitates were kept in separate containers and were added separately to the tank following addition of all conventional debris. The chemical-precipitate containers were shaken just prior to addition of the container contents to the tank. The debris was introduced at the top of the tank and transported toward the strainer array by the water flow drawn through the strainers. The non-chemical effects tests added debris at the back corner of the tank. The chemical-effects tests added debris at the front corner of the tank. The difference in location is that the non-chemical effects test used a diffuser, and debris was added in the vicinity of the diffuser to maximize entrainment of the debris.

The non-chemical effects tests included the use of a diffuser attached to the return line as well as periodic manual stirring. The chemical-effects tests included the use of a sparger attached to the return line as well as periodic manual stirring. Any material that settled in the corners or on the floor of the tank was qualitatively assessed in the test observations or with the use of test photographs. The amount of settled material was minimal.

The diffuser and sparger were designed to disperse tank return flow and debris, reduce localized turbulence on the strainer modules, and prevent direct impingement on the strainer modules while entraining material by increasing turbulence away from the strainers. The sparger was located at the bottom back of the tank and discharged the water toward the front of the tank across the width of the tank floor.

Introduction of the debris at the top front corner of the tank and the dispersing flow from the sparger ensured the debris reaching the screens was thoroughly mixed, well dispersed, and capable of being transported to the strainers by the low strainer approach velocity. This test method effectively prevented large agglomerations of debris. Manual stirring of debris that settled to the floor of the tank ensured debris did not remain on the tank floor and that debris had multiple opportunities to settle on the screens.

NRC Request 17:

Please explain whether the stirring used to prevent debris settlement did or did not non-prototypically affect bed formation, and provide a basis for this conclusion.

HNP Response:

The HNP non-chemical effects testing included the use of a diffuser as well as periodic manual stirring. The HNP chemical-effects testing included the use of a sparger as well as periodic manual stirring. Manual stirs are performed at various points during the test to re-circulate debris that collects on the bottom of the tank. Each stir was performed with a 6 foot long canoe oar. The broad end of the oar was gently placed in the water, and the oar was slowly skimmed across the bottom of the tank toward the strainer array. Although stirring did reduce the amount of debris on the floor of the tank, the stirring resulted in little to no increases in head loss and turbidity. Any material that settled in the corners or on the floor was qualitatively documented in the test observations or with the use of test photographs. This small amount of material, when mixed back in with the tank test flow would re-accumulate and settle in the corners. The observation of re-settling debris combined with a lack of head loss increase after stirring suggests that there will be no more accumulation of debris on the screen at the tested approach velocity.

The stirring did not non-prototypically affect bed formation because stirring occurred in the test tank at a far enough distance from the strainer such that the debris bed was not disturbed. The debris was stirred to suspend the debris in order for the pool turbulence and screen approach velocity to transport the debris to the strainer.

NRC Request 18:

Please provide the percentage by type of debris that settled in the test tank for each test.

HNP Response:

Through the use of the test plan, test logs, and photographs, an approximate percentage by type of debris that settled in the test tank was determined. If no information or notes were provided in the test logs regarding settling of debris, then photographs of the test were relied upon to determine a percentage by debris type of settled debris. For one test, in-test photographs were used because the process of draining the tank could wash debris off of the strainer array. For the other three tests, the tank was too cloudy at the conclusion of the test for in-test photographs to be of use. For these tests, post-test photographs were used. As discussed in RAI 17, repeated attempts to get the settled debris onto the strainer through manual stirring were not successful; at the tested approach velocity, the strainer could not retain any additional debris.

For Test 1 (fiberglass) in-test photographs were used. It was conservatively estimated that 5 to 10 percent of the low-density fiberglass settled and 10 to 15 percent of the dirt/dust surrogate was estimated to have settled. Negligible amounts of the coatings particulate surrogate and sodium aluminum silicate were estimated to have settled.

For Test 2 (Microtherm), post-test photographs were used. No settled fiber was observed. An estimated 5 to 10 percent of the dirt/dust surrogate settled. Negligible amounts of the coating particulate surrogate, Microtherm, sodium aluminum silicate, and aluminum oxyhydroxide were estimated to have settled.

For Tests 3 and 4 (Min-K), post-test photographs were used. No settled fiber was observed. An estimated 5 to 10 percent of the dirt/dust surrogate settled. Negligible amounts of the coating particulate surrogate, Min-K, sodium aluminum silicate, and aluminum oxyhydroxide were estimated to have settled.

NRC Request 19:

Please provide information that shows a valid thin bed test was conducted. In doing so for the thin-bed test: (1) please verify that fibrous debris preparation and introduction would result in prototypical transport and bed formation (note that the staff considers that the most transportable debris will reach the strainer first); (2) please verify that flow conditions including any stirring used during testing would allow prototypical bed formation; (3) please verify that the installation of the debris bypass eliminator (DBE) would not change the prototypicality of bed formation on the strainer, or verify that test was conducted with the same top hat arrangement (no DBE) installed in the plant; and (4) please verify that various incremental amounts of fiber were used in conjunction with limiting particulate debris loads during thin bed testing.

HNP Response:

For all tests, the fibrous debris was prepared as discussed in the response to RAI 15. The fiber and particulate were then mixed thoroughly with a paint mixer attached to an electric drill until a homogeneous slurry was formed. The size of the fibrous debris ranged from individual fibers to small (approximately <1 inch) tufts. Fines were used for all of the particulate debris. Therefore, all of the debris used in the testing was considered to be highly transportable. For all tests, the debris was introduced at the top of the tank and transported toward the prototypical strainer array by the water flow drawn through the strainers. The test top strainer modules were mounted vertically in an array on a plenum. Walls were installed on three sides of the strainer array to simulate the hydraulic effects of the sump pit walls and adjacent strainer modules in the plant sump strainer array. The front of the test strainer array was located in close proximity to the tank wall, which is representative of a fourth wall. Recirculated water was introduced to the tank such that the return flow did not directly impinge on the surfaces of the top hats. For the non-chemical effects testing, an electric propeller (operated continuously) and manual stirring with a wooden oar were used to keep debris suspended to assure transport to the strainer assembly and prevent non-prototypical settling on the tank floor. For the chemical-effects testing, a sparger and manual stirring with a wooden oar were used to keep debris suspended.

The diffuser that was used in the non-chemical effects testing and the sparger that was used in the chemical-effects testing were designed to disperse tank return flow and debris, reduce localized turbulence on the strainer modules, and minimize direct impingement on the strainer modules while entraining material by increasing turbulence away from the strainer modules. The diffuser was located along one of the sides of the tank; the sparger was located at the bottom back of the tank and discharged the water toward the front of the tank across the width of the tank floor. Manual stirring was performed in a manner that did not affect the debris bed and provided multiple opportunities for the debris to be transported to the strainer modules. These methods result in conservative transport and prototypical bed formation.

The non-chemical effects testing consisted of four tests: a thin-bed fibrous test (1/8 inch theoretical fiber bed), a full-load fibrous test (0.78 inch theoretical fiber bed), a Microtherm test, and a Microtherm confirmatory test (0.05 inch theoretical fiber bed). The chemical-effects testing consisted of four tests: a full-load fibrous test, a Microtherm test, a Min-K test, and a Min-K test without the debris bypass eliminator test. Through these eight tests, various incremental amounts of fiber were tested. All tests, except for the Min-K without the debris bypass eliminator, were performed with the DBE installed. All testing to date performed by Alion has shown that testing with the DBE installed results in significantly higher head loss than testing without the DBE and that testing with the DBE results in a more uniform formation of the debris bed than testing without the DBE. HNP's two Min-K tests follow these trends.

The non-chemical effects testing showed that measured head loss was significantly higher for the full-load test versus the thin-bed test; a thin-bed effect was not observed. Additionally, the non-chemical effects Microtherm test resulted in higher head loss than both the thin-bed and full-load fibrous debris tests.

As mentioned above, the Microtherm tests had a theoretical fiber bed thickness of 0.05 inches, based on the latent fiber and the Temp-Mat and not the fiber contained within the Microtherm. The theoretical fiber bed for the Min-K tests is 0.038 inches, based on only the latent fiber and not the fiber contained within the Min-K. All of the fiber for these tests was added in a single debris addition; incremental batching of the fiber was not necessary.

NRC Request 20:

Please provide a basis for the use of the broad range of 2.5 to 20 micron diameter particles for Min-K and Microtherm debris during head loss testing.

HNP Response:

Microtherm and Min-K consist of two different-sized particles, titanium dioxide and fumed silica particles.

For Microtherm, according to the material vendor, the titanium dioxide particles are irregular but broadly spherical in shape, with a particle size centered around 2.5 microns. For Min-K, according to the material vendor, the titanium dioxide particles are less than five microns in diameter. The Microtherm vendor has stated that the fumed silica is a slightly larger and more complex particle, as it is formed of spherical primary particles that are fused together into irregular three-dimensional branched chain aggregates that are further mechanically entangled into porous agglomerates that are approximately spherical. The diameters of the agglomerates are centered very roughly around 20 microns. The agglomerates can be regarded as the fundamental particle because breaking the agglomerates down to aggregates smaller than the 20 micron particle requires significant dispersion energy in a high-shear mixer and the use of dispersants.

The Microtherm and Min-K used in the head-loss testing were purchased in the powder form; measurement of the particle sizes was not performed.

NRC Request 21:

The submittal stated that the vortexing evaluation was completed using RHR pump runout flow (4500 gallons per minute). It is not clear that containment spray (CS) flow was included in the *evaluation. It is also not clear that testing or the clean strainer head loss (CSHL) calculation included the CS flow. Please provide the pump flows that were used to provide inputs for head loss scaling and the bases for these flows. Please provide the same information for the flows used in the CSHL calculation. Please verify that these are maximum system flows and include both RHR and CS pump flows.*

HNP Response:

Each sump contains separate suction pipes for the RHR pump associated with the sump and the CS pump associated with the sump. The RHR and CS sections of the sump are separated by a concrete wall (the wall contains a flow-balancing opening at the bottom). The vortexing evaluation is based on a maximum RHR flow of 4,500 gpm, which bounds the maximum flow rate of 1,863 gpm from the sump to the CS pump.

The flow rates of 5,754 gpm (single-train operation) and 6,363 gpm (two-train operation with the single failure of one RHR pump) provided in the supplemental response represent the worst-case flow rates through the combined RHR and CS sections of the sump for the limiting pump combinations. These flow rates are maximum system flows and include both RHR and CS pump flows. The response to RAI 26 provides the basis for determining these maximum system flows.

The head loss testing and associated head-loss scaling is based on a maximum sump flow rate of 5,754 gpm (single-train operation). Flow sweeps were also performed at the scaled equivalent to the higher flow rate of 6,363 gpm. The full-train operation of both sumps is not a limiting case because the debris would be distributed across both sump screens rather than across a single screen given a single train failure, and the flow rate through each sump would be lower than the flow rate through the sump with the operating RHR pump given a single failure of a RHR pump. Similarly, operation of both sumps with the failure of one RHR pump is not a limiting case because the debris is split between the two sumps.

The clean strainer head-loss calculation is based on a sump flow rate of 6,363 gpm.

NRC Request 22:

Please provide justification for neither running the high fiber and Microtherm tests (Tests 1 and 2) until a steady state was reached nor extrapolating the data to the emergency core cooling system mission time. Alternatively, please extrapolate the test data to the mission time and provide a new strainer head loss value.

HNP Response:

The termination criteria for the head-loss testing were:

- At least five pool turnovers have occurred, and
- The differential pressure across the debris bed changes by less than or equal to 1 percent over a one-hour period.

All of the head-loss testing HNP has conducted, including the high fiber and Microtherm tests (Tests 1 and 2), have satisfied these criteria. Therefore, the extrapolation of the most limiting chemical-effects test head loss results bounds the extrapolation of the high fiber and Microtherm tests. As discussed on page A1-61 of the supplemental response, assuming the most limiting chemical-effects test had head loss that was increasing at 1 percent per hour at the time the testing was secured, the rate of increase would be 0.036 ft/hr, based on a head loss of 3.57 feet at test conditions at the termination of the test. Assuming this increase would be constant over 720 hours results in an increase in head loss of 25.92 feet. This increase was shown to be more than offset by the increased NPSH available due to sump subcooling. The head loss at the end of Test 1 was 2.60 feet at test conditions, and the head loss at the end of Test 2 was 3.42 feet at test conditions. A constant increase of 1 percent per hour for 720 hours results in an increase in head loss of 18.72 feet for Test 1 and an increase in head loss of 24.62 feet for Test 2. These values are bounded by the increase in head loss described above.

Based on a review of the test logs, for Test 4 (the most limiting chemical-effects test), the head loss at the end of the test, when the head loss was declared stable, was not increasing. Based on a review of the test logs, for Tests 1 and 2, over the final hours of the test from the final debris addition to the termination of the test, when the head loss was declared stable, the rate of increase of the head loss was decreasing. Based on these conclusions, linear extrapolation is a conservative method for extrapolating the test data to the mission time.

NRC Request 23:

Please identify whether any extrapolation of test data to different flow rates or temperatures lower than the test temperature was performed. If these extrapolations were conducted, please provide information that shows that the methods provided prototypical or conservative results. Please include a description of any data manipulation that was used to determine the final head loss.

HNP Response:

The debris head loss test report extrapolated the test data to different flow rates (for parametric evaluations of changes in screen area) and to temperatures lower than the test temperature (for evaluation of structural design).

The measured head loss was extrapolated to a different flow and/or temperature using the following equation:

$$\Delta H_2 = \Delta H_1 \left[R_L \left(\frac{\mu_2}{\mu_1} \right) \left(\frac{U_2}{U_1} \right) + R_T \left(\frac{\rho_2}{\rho_1} \right) \left(\frac{U_2^2}{U_1^2} \right) \right]$$

where:

R_L = ratio of laminar flow
μ= dynamic viscosity at temperature (lbm/ft/sec)
U= approach velocity (ft/sec)
R_T = ratio of turbulent flow
ρ = density at temperature (lbm/cu.ft)

Flow sweeps were performed in each of the test series, specifically clean strainer flow sweeps and flow sweeps after a stable, debris-induced head loss has been achieved. For each of the flow sweeps, a quadratic equation was generated that closely matches the curve of the data. In those equations, the second-order term represents the turbulent contribution to the head loss while the linear term represents the laminar contribution. The contribution of each to the overall flow regime is determined through substitution of a representative approach velocity into the quadratic equations. Once each term is computed, their relative magnitude is compared in order to quantify the laminar/turbulent split.

Based on the results of the chemical effects testing, the measured head loss can be conservatively corrected for increases in temperature or flow using a 50 percent laminar term and a 50 percent turbulent term and can be conservatively corrected for decreases in temperature or flow using a 100 percent laminar term and a 0 percent turbulent term. This results in conservative head loss corrections, regardless of the actual laminar/turbulent split and is bounding for all chemical-effects tests. It is also conservative for the thinner bed tests because they are closely related to a clean strainer and thus within the laminar flow regime. Using the above equation, to correct using a 50 percent laminar term and 50 percent turbulent term, the R_L term is set to 0.50 and the R_T term is set to 0.50. To correct using a 100 percent laminar term and 0 percent turbulent term, the R_L term is set to 1 and the R_T term is set to 0.

SHEARON HARRIS NUCLEAR POWER PLANT, UNIT NO. 1
DOCKET NO. 50-400/LICENSE NO. NPF-63
RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION
REGARDING SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02

NRC Request 24:

It is not clear to the staff that the 0.12 ft of head loss discussed at the bottom of page A1-27 of Attachment 1 to the supplemental response is equal to the clean strainer head loss measured during testing. Please provide the clean strainer head loss measured during testing at the design flow rate.

HNP Response:

The value of 0.12 feet for the clean strainer head loss was determined by prototype testing performed by Enercon with the debris bypass eliminator included. The clean strainer head loss, as determined by chemical-effects testing performed by Alion at the design flow rate, was 0.0404 feet, 0.0443 feet, and 0.0459 feet (three tests with the debris bypass eliminator), and 0.0163 feet (one test without the debris bypass eliminator).

NRC Request 25:

Please provide a summary description and results of an evaluation of whether flashing across the strainer and debris bed could occur, including assumptions and bases for the evaluation.

HNP Response:

The minimum submergence of the sump strainer is 0.35 feet, and the maximum head loss across the strainer and debris bed is 2.34 feet. The minimum partial pressure of dry air in containment is 10.4 psia or 24 feet, assuming containment is at the design pressure of -2 psig and at a temperature of 130°F, which bounds the maximum value of 120°F allowed by Technical Specifications.

The minimum head pressure downstream of the screens is 24 feet + 0.35 feet – 2.34 feet = 22 feet above saturation pressure. The water will therefore be maintained above saturation pressure downstream of the debris bed, and flashing will not occur.

NRC Request 26:

Please describe the methodology used to compute the maximum pump flows for the RHR and CS pumps (e.g., the maximum runout flow from vendor pump curves, and a hydraulics program which calculates the flows for various system lineups).

HNP Response:

The RHR pump flow for recirculation was determined by Westinghouse to be 3,891 gpm. Although this value of flow is less than the pump runout flow rate of 4,500 gpm, it is considered to be representative of the expected RHR recirculation flow.

The containment spray flow for recirculation is determined by deriving a system resistance curve based on resistance data from the Hydraulic Institute and plotting this curve on a total developed head (TDH) curve for the CS pump. The intersection of the system resistance curve and the TDH curve is the CS pump flow. This pump flow is 2,110 gpm, and this value of flow is used in the net positive suction head available calculation for the CS pumps. The delivered CS flow is determined by subtracting the pump recirculation flow rate of 247 gpm, which is determined in a similar manner, from the pump flow rate, resulting in a delivered flow rate of 1,863 gpm.

NRC Request 27:

Net positive suction head results were not reported for the hot leg recirculation configuration. Please describe why the hot leg recirculation configuration is bounded by the results presented in the supplemental response, or provide separate results for that configuration.

HNP Response:

The flow rates of 5,754 gpm (single-train operation) and 6,363 gpm (two-train operation with the failure of one RHR pump) provided in the supplemental response represent the worst-case flow rates for the respective pump combinations. The procedure for transferring between cold-leg recirculation and hot-leg recirculation does not secure the RHR pumps. This procedure does secure the charging and safety injection pumps (CSIPs), but then restarts them. Thus, hot-leg recirculation uses the same pump combination that is employed during cold-leg recirculation. For hot-leg recirculation, the RHR flow path is reduced from two safety injection (SI) headers to a single header, which would result in greater downstream flow resistance during hot-leg recirculation. This is supported by test data from plant startup, which shows the RHR flow during hot-leg recirculation to be about four percent less than for cold-leg recirculation. Therefore, the hot-leg recirculation configuration is bounded by the cold-leg recirculation configurations described in Section 3.g of the supplemental response.

NRC Request 28:

On page A1-46 of the supplemental response it is stated that: "Because the recirculation sump structures are not subject to the effects of pipe whip and jet impingement, the recirculation sump *screens inside the sump structures are also not subject to the effects of pipe whip and jet impingement." The conclusion for the sump screens is based upon the statement regarding the sump structures.*

However, no justification or basis (e.g. separation distance, physical shielding, absence of high energy sources, etc.) is cited for the validity of the sump structure statement. Please provide a summary of the evaluations performed for dynamic effects which lead to the conclusion that neither the sump structures nor the sump screens are subject to the effects of pipe whip and jet impingement associated with high-energy line breaks.

HNP Response:

The HNP containment sumps are structures that are located outside the secondary bio-shield wall on the northeast and southeast sides of the containment building and are separated by ninety degrees of arc.

A review of the pipe break location figures in FSAR section 3.6A determined that there are no potential high-energy line breaks that could result in jet impingement or pipe whip damage to the strainer. In addition, the vertical trash racks, the vortex suppressor grating, the diamond plate installed above each sump, and the concrete walls surrounding each sump provide additional protection to the strainers. Also, because of the redundancy of the two sumps and their physical separation, a single jet or pipe whip could not damage both sump strainers. Therefore, the strainer assembly is adequately protected from the hazardous effects of high-energy line breaks. Finally, the replacement strainers are in the same locations as the original strainers, which were determined to not be susceptible to detrimental effects associated with high-energy line breaks.

NRC Request 29:

The supplemental response stated that 0.6 ft^3 of fiber is required for a 1/8th inch thin bed formation (reduced from a calculated 0.8 ft^3 for conservatism), yet only 0.33 ft^3 of fiber "long enough to be caught on the underside of the fuel assemblies" can be bypassed. Thus, the supplemental response concluded that no thin bed can form on the fuel assembly inlets. There are three main reasons for considering that this argument may be oversimplified.

First, not all of the bypassed fiber needs to be long enough to collect on the underside of the fuel assemblies to form the debris bed. Once some fiber that is long enough to collect there arrives (in total there is enough to get roughly halfway to 1/8th inch), additional fiber will only need to be collected on the accumulated fiber layer, through which the openings will be much smaller than the clean fuel assembly openings. Shorter fibers could then easily accumulate and make up the remainder of the thin-bed layer needed to cause head loss.

Second, shorter fibers will also accumulate around the edges of the fuel assembly structures, even before substantial accumulation of long fibers, and facilitate the formation of the filtering fiber layer. Third, debris beds thinner than 1/8th inch can filter particulate and cause head loss, which is particularly true in the presence of microporous insulations such as Microtherm and Min-K, as well as precipitates.

Please describe the methodology used to determine that the amount of fiber that bypasses the recirculation sump screens is 0.33 ft^3. Also, in light of the three reasons stated above, please provide additional information to address the potential for thin-bed formation at the HNP fuel assembly inlets. Specifically, please describe the criteria used to determine the minimum length fiber which would be captured at fuel assembly inlets.

HNP Response:

The following information is provided to respond directly to this RAI. However, HNP will verify that plant conditions, including parameters related to core inlet blockage, are bounded by the final WCAP-16793-NP and the corresponding final NRC staff SE as stated in the response to RAI 31.

The minimum length of a fiber that could be captured at the inlets of a fuel assembly is based on an AREVA drawing that shows the minimum nominal blade-to-blade gap of a FUELGUARD assembly to be 0.067 inches (1,702 microns).

HNP conducted plant-specific bypass testing to quantify and characterize the fibers that could pass through the replacement strainers. This testing showed that 9.15 percent of the fiber that reaches the screen passes through the screens. Of this fiber that passed through the screens, the longest fiber measured was 1,906 microns. This length exceeds the minimum dimension of the FUELGUARD assembly as described above. However, of all of the fibers characterized by optical microscopy, only three were longer than 1,702 microns. All three of these fibers came from filter bag A, from which 160 fibers were measured. Thus, only three of 160 fibers (1.9 percent) are longer than the minimum dimension. Considering only the optical microscopy results of filter bag A in determining the percentage of long fibers is conservative. Optical microscopy of filter bag B showed that all of the 140 fibers measured were shorter than this minimum dimension. If these additional fiber measurements are considered, only 3 of 300 (1 percent) fibers are longer than this minimum dimension.

The crossover leg break is the limiting break with respect to the amount of fiber that reaches the recirculation sump screen. For this break, a total of 187.2 cubic feet (fiberglass insulation plus latent fiber) of fibrous debris reaches the sump screen. Of this, 9.15 percent passes through the screens, for a total of 17.13 cubic feet. Of this amount, only 1.9 percent are longer than the minimum clearance in the FUELGUARD assembly, resulting in 0.33 cubic feet that is longer than the minimum clearance.

0.33 cubic feet is roughly half of 0.6 cubic feet (the amount of fiber required for a bed one-eighth inch thick). However, there are two significant conservatisms in the calculation of both the 0.33 cubic feet and 0.6 cubic feet values. As stated above, 1 percent is a more realistic value for the percentage of long fibers instead of using 1.9 percent. If 1 percent is used, the 0.33 cubic feet value is reduced to 0.17 cubic feet. Additionally, 0.6 cubic feet was reduced from 0.8 cubic feet for conservatism. If these conservatisms are removed, 0.17 cubic feet is well below half of 0.8 cubic feet. Additionally, an implicit conservatism of this analysis is that all of the long fibers are assumed to be oriented with the longitudinal axis transverse to the direction of flow such that both ends of the fiber touch the edges of the FUELGUARD channel. In reality, a piece of fiber with the length-to-diameter ratio of the long fibers would likely be oriented with the longitudinal axis parallel to the flow, such that the fibers would flow through the FUELGUARD channel. So even though some fiber is longer than the minimum FUELGUARD clearance, the fiber may not collect as a larger portion of the fiber will flow through the FUELGUARD openings.

For the breaks involving Microtherm and Min-K, significantly less fiber reaches the screens. Using the same methodology as described above for the crossover-leg break and considering the small amount of fiber contained within the microporous insulation, the Microtherm case results in 0.021 cubic feet of fiber that is longer than the minimum clearance of the FUELGUARD assembly, and the Min-K case results in 0.02 cubic feet of fiber that is longer than the minimum clearance of the FUELGUARD assembly. These values are well below roughly half of 0.6 cubic feet (reduced from a calculated 0.8 cubic feet for conservatism), even when using the conservative value of 1.9 percent for the percentage of fibers longer than the minimum clearance.

NRC Request 30:

The in vessel downstream effects section of the February 28, 2008, supplemental response states: "The potential to locally block flow at the fuel spacer grids was also considered in the AREVA evaluation; a one-inch long solid plug around the limiting fuel pin at the peak power location was postulated. It was conservatively shown that the cladding temperature at the center of the plug is 1,029 °F [degrees Fahrenheit], which is well below the 10 CFR 50.46 [Title 10 Code of Federal Regulations, Section 50.46] acceptance criterion of 2,200 °F."

The staff believes and plans to document in its final SE on the topical report, WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid," that, should a licensee calculate a temperature that exceeds 800 °F, the licensee should justify through analysis of cladding strength data for oxidized or pre-hydrided cladding material, the acceptability of the higher temperature reached. Therefore, *please justify the acceptability of exceeding 800 °F cladding temperature. The staff also notes that the March 28, 2008, supplemental response shows a peak fuel temperature of 395 °F. Please reconcile the difference between the peak temperatures described in the two submittals.*

HNP Response:

In 2006, HNP contracted AREVA to estimate the effect on core cooling at HNP from debris that may enter the reactor vessel from containment when the ECCS suction is switched to the containment sump. This assessment used the guidance in WCAP-16406-P. WCAP-16406-P did not include guidance for evaluating blockage of the internal spacer grids. Although it is improbable that a buildup of debris may occur that completely blocks a fluid sub-channel at the inlet to a spacer grid around a single rod, an evaluation was performed to demonstrate that even for this situation the cladding would be successfully cooled. AREVA performed an assessment of a complete blockage by considering a solid plug around the limiting fuel pin at the peak power location. The following assumptions were made in the calculation:

- The blockage is at the hot spot on the peak power rod
- Axial conduction in the fuel is neglected.
- The surface of the cladding over the length of the blockage is assumed to be adiabatic.
- A conservative value of thermal conductivity of the cladding is used.

The calculation models the fuel cladding as a plane wall with uniform energy generation per unit volume. For axial conduction along the cladding, the heat transfer area is the cross-sectional area of the cladding. The conduction length is half of the plug thickness. The energy deposited in the cladding inside the plug is calculated based on the core power at the peak power location and the core decay heat. The sink temperature is the fluid saturation temperature at the core pressure, plus 15 degrees F to account for nucleate boiling. The calculation was performed with a postulated complete blockage of one inch in length, which resulted in a cladding temperature at the blockage centerline of 1,029 degrees F.

Subsequent to the completion of this calculation, additional guidance and calculations for blockage at intermediate spacer grids was developed by the Pressurized Water Reactor Owners Group (PWROG) and issued in WCAP-16793-NP, Revision 0. The approach for determining the cladding temperature at spacer grids is described in Section 2.2 and Section 4. A calculation method was also presented to determine the cladding temperature as chemical deposits build up on the cladding surface (LOCADM). LOCADM is fundamentally different from the calculation described above in that LOCADM is a much more complex tool than the unidirectional conduction model used by AREVA. The result is a demonstration that the AREVA calculation described above (which neglects radial conduction and only considers axial conduction) is overly conservative.

The calculation that determined a cladding temperature of 1,029 degrees F was an early and overly conservative method to proactively address a potential concern. Subsequently, LOCADM was used to conservatively determine the maximum cladding temperature to be approximately 395 degrees F. There is no expectation that the cladding temperature will exceed 800 degrees F. The calculation using LOCADM to determine the cladding temperature of 395 degrees F takes precedence over the earlier calculation that determined a cladding temperature of 1,029 degrees F.

NRC Request 31:

The NRC staff considers in-vessel downstream effects to not be fully addressed at HNP as well as at other PWRs. The HNP GL 2004-02 submittal refers to the draft WCAP-16793-NP. The NRC staff has not issued a final SE for WCAP-16793-NP; nor is the staff aware that satisfactory testing for a problem bed of debris at the core inlet has been performed for HNP plant conditions and fuel type. The licensee may demonstrate that in-vessel downstream effects issues are resolved for HNP by showing that the licensee's plant conditions are bounded by the final WCAP-16793-NP and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating, without reference to WCAP-16793-NP or the staff SE, that in-vessel downstream effects have been addressed at HNP.

HNP Response:

HNP will report how it has addressed the in-vessel downstream effects issue per the guidance contained in the NRC letter dated September 29, 2008, within 90-days of issuance of the final NRC Safety Evaluation on WCAP-16793-NP. (Reference Attachment 2, Regulatory Commitment).

NRC Request 32:

Follow up calculations on spray and sump potential hydrogen (pH) values were noted (but not provided) on page A1-59 of the supplemental response since the amount of sodium hydroxide (NaOH) that can be added is greater than what was used in the calculations of maximum sump and spray pH. The additional NaOH beyond that assumed in the pH calculations could render those calculations non-conservative. Please explain how much additional chemical precipitate is predicted by topical report, WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," spread sheet using the higher NaOH amounts with all other input parameters constant. Also, please explain whether the amount of chemical precipitate used in the head loss testing at Alion bounded the amount that was predicted by the

WCAP-16530-NP base model with the higher NaOH amounts. If not, please discuss why the head loss test results remain conservative.

HNP Response:

The following table lists the quantities of chemical precipitates predicted to form for the analysis of record (and discussed in our supplemental response) and the estimated quantities of chemical precipitates due to the increase in NaOH flow with all other input parameters constant, and due to the increase in NaOH flow with credit taken for actual plant parameters that existed during the period the NaOH flow could have been higher than that assumed in the analysis of record. It is important to note that the condition which created the potential for NaOH flow rate to be higher than design has been corrected. Therefore, the "analysis of record" precipitate quantities reported in the table below are currently valid.

		Analysis of Record	Higher NaOH flow, all other input parameters constant	Higher NaOH flow, credit for actual plant parameters
Fiberglass	NAS	108.72 kg	182.78 kg	99.93 kg
	AlOOH	0 kg	0 kg	0 kg
Microtherm	NAS	35.53 kg	35.52 kg	35.53 kg
	AlOOH	11.33 kg	28.18 kg	9.77 kg
Min-K	NAS	33.81 kg	33.80 kg	33.81 kg
	AlOOH	11.52 kg	28.37 kg	9.97 kg

As can be seen from the table, the higher NaOH flow with all other input parameters constant does represent an increase in chemical precipitates from the analysis of record. However, actual plant parameters (Refueling Water Storage Tank level, Containment Spray Additive Tank level, and Containment Spray Additive Tank NaOH concentration) that existed during the time interval in which the NaOH flow could have been higher reduce the quantities of chemical precipitates to levels that are bounded by the analysis of record.

The head loss testing conducted by Alion used values of chemical precipitates from the analysis of record and scaled by the ratio of the test net strainer area to the net strainer area with miscellaneous blockage. Thus, the head-loss testing does not bound the hypothetical case of increased NaOH flow with all other inputs unchanged from their design values. However, actual plant parameters during the time interval in which the NaOH flow could have been higher reduce the quantities of chemical precipitates to levels that are bounded by the head-loss testing.

SHEARON HARRIS NUCLEAR POWER PLANT, UNIT NO. 1
DOCKET NO. 50-400/LICENSE NO. NPF-63
RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION
REGARDING SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02

NRC Request 33:

The licensee performed integrated head loss testing prior to the revision to WCAP-16530-NP that changed chemical precipitate settling rates. The supplemental response indicates that some of the chemical precipitate settling did not meet the minimum revised criteria in WCAP-16530-NP. Please estimate the percentage of debris and chemical precipitate that settled during testing and discuss what steps were taken to ensure the chemical precipitate added to the test was transported to the test strainer.

HNP Response:

As stated in RAI 18, based on a review of test photographs, no appreciable chemical precipitate settling was observed during testing.

The chemical precipitates were introduced at the top of the tank and transported to the strainer array by the water flow drawn through the strainers. Chemical precipitates were added in the front corner of the tank to suspend the debris to allow for motion of water in the tank to transport the debris to the strainer array. A sparger system and periodic manual stirring were employed to keep the debris suspended in the fluid and prevent non-prototypical settling on the tank floor.

SHEARON HARRIS NUCLEAR POWER PLANT, UNIT NO. 1
DOCKET NO. 50-400/LICENSE NO. NPF-63
RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION REGARDING SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02
LIST OF REGULATORY COMMITMENTS

The action in this document committed to by Harris Nuclear Plant (HNP) regarding Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Bases Accidents at Pressurized-Water Reactors," is identified in the following table. Statements in this submittal, with the exception of those in the table below, are provided for information purposes and are not considered commitments. Please direct any questions regarding this document or any associated regulatory commitments to the Supervisor, Licensing/Regulatory Affairs.

Item	Commitment	Completion Date
1	HNP will report how it has addressed the in-vessel downstream effects issue per the guidance contained in the NRC letter dated September 29, 2008 (ML082540269).	Within 90 days of issuance of the final NRC Safety Evaluation on WCAP-16793-NP.