FPL

MAR 19 2009

L-2009-062
10 CFR 50.54(f)

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

RE: Florida Power & Light Company
Turkey Point Unit 4
Docket No. 50-251

Subject: Response to NRC Request for Additional Information Regarding the Responses to GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," TAC NO. MC4726

References:

(1) Letter from B. L. Mozafari (U. S. Nuclear Regulatory Commission) to J. A. Stall (FPL), "Turkey Point Nuclear Plant, Unit 4 - Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors, Request for Additional Information (TAC NO. MC4726)," dated December 19, 2008 (ML083440078)

(2) Letter L-2008-033 from W. Jefferson, Jr. (FPL) to U. S. Nuclear Regulatory Commission, Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated February 28, 2008 (ML080710429)

(3) Letter L-2008-160 from W. Jefferson, Jr. (FPL) to U. S. Nuclear Regulatory Commission, Updated Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated August 11, 2008 (ML080710429)

(4) Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004 (ML042360586)

This submittal provides the Florida Power and Light Company (FPL) responses to the U. S. Nuclear Regulatory Commission (NRC) request for additional information (Reference 1) regarding our Supplemental Information provided previously (References 2 and 3) on the subject of the NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors" (Reference 4).

Attachment 1 provides the Turkey Point Nuclear Plant, Unit 4 (PTN4) responses to the request for additional information. The supplemental information previously provided, in References 2 and 3, continues to apply. This information is being provided in accordance with 10 CFR 50.54(f).

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NRR

This information is being provided in accordance with 10 CFR 50.54(f).

As part of this response, there were two commitments made, as follows:

1. FPL will analyze a sodium tetraborate sample to ensure its suitability and will periodically re-sample. FPL will proceduralize this requirement.

2. FPL will update the UFSAR to include references to the Unit 3 and Unit 4 plant change modification documents that implemented the changes to address the NRC Generic Safety Issue 191, "Assessment of Debris Accumulation on PWR Sump Performance.

Please contact Mr. Robert Tomonto, at (305) 246-7327, if you have any questions regarding this response.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on March 19, 2009.

Sincerely yours,

William Jefferson, Jr.
Site Vice President
Turkey Point Nuclear Plant

Attachment: (1)

cc: NRC Regional Administrator, Region II
USNRC Project Manager, Turkey Point Nuclear Plant
Senior Resident Inspector, USNRC, Turkey Point Nuclear Plant

# ATTACHMENT 1
# Responses to NRC's Request for Additional Information on FPL's Turkey Point Nuclear Plant Unit 4 (PTN4) GL 2004-02 Response Dated February 28, 2008 and Supplemental Response dated August 11, 2008

## Overview of Turkey Point Unit 4 (PTN4) Conservatisms

In FPL's Supplemental Response of August 11, 2008, FPL summarized some of the actions and analyses that provided conservatism and margin to PTN4 compliance with GL 2004-02. These included:

- The new sump strainer system installed in Turkey Point Unit 4 in the spring of 2008 is a Performance Contracting, Inc., design with a surface area of approximately 3,600 $ft^2$ with 3/32-inch perforations to retain debris. The new strainers replaced the previous sump screens which had a combined total surface area of approximately 63 $ft^2$ with a ¼-inch screen mesh.
- Debris interceptors have been installed at the exit points at the bioshield wall. These debris interceptors have been demonstrated to hold a significant amount of debris from a large break LOCA inside the biowall.
- In the debris generation analysis, the Zone of Influence (ZOI) used for Nukon insulation is 17D for piping and 7D for the steam generators. WCAP-16170-P testing confirmed that the zone of influence could be reduced further to 5D. As such, the strainer system was qualified utilizing a quantity of fiber that is significantly greater than is expected to be generated.
- A uniform factor of 1.1 has been applied to the ZOI radius to ensure the calculation was conservative.
- 100% of unqualified coatings in the active pool, regardless of types and location inside containment, were assumed to fail as particulates and transport to the screen. EPRI and industry testing indicates some unqualified coatings do not fail and some coatings fail as chips and may not transport to the sump.
- Scaling for the head loss testing was based on a strainer area of 3513.8 $ft^2$ (3613.8 - 100). 100 $ft^2$ was subtracted from the total strainer area to account for miscellaneous debris such as tags and labels even though testing indicated that these items will not transport to the screen.
- In determining the velocity profile for testing, the computational fluid dynamics (CFD) analysis calculated the average velocities by "double weighting" the fastest velocity at the increment under consideration. Weighting the average by twice the fastest velocity incorporates conservatism into the calculation.

The following responses to NRC's RAIs provide another opportunity to discuss, in more detail, Turkey Point Unit 4 analyses and conservatisms. This should facilitate NRC's review and conclusion that Turkey Point Unit 4 design and analyses are conservative, and demonstrate that there is sufficient ECCS NPSH margin available as required by GL 2004-02.

RAI 1

Please provide clarification of whether the containment spray system (CSS) is required to operate in recirculation mode for a secondary system high energy line break (HELB). If the CSS is required to operate in recirculation mode following a secondary system HELB, please describe your evaluation of this event including the performance of the new sump strainer.

RESPONSE

As asked by NRC in an earlier RAI 34, February 8, 2006, and answered in the Turkey Point Unit 4 (PTN4) August 11, 2008 Supplemental Response to GL 2004-02, Attachment 2, page 8 of 78, the ECCS, which includes the containment spray system, is not required to operate in the recirculation mode following a secondary system high energy line break.

RAI 2

Please provide your evaluation that establishes that breaks at or near the reactor nozzle will not result in a more limiting debris generation condition than the breaks presented in the supplemental response. Please describe the insulating material(s) for the reactor vessel.

RESPONSE

Break locations were determined in accordance with Section 3.3.4 of NEI 04-07 and Regulatory Guide 1.82. All RCS piping and attached energized piping is evaluated. For PTN4 the analyzed locations were:

- Breaks in the reactor coolant system (e.g., hot leg, crossover leg, cold leg, pressurizer surge line), main steam, and main feedwater lines with the largest amount of potential debris within the postulated ZOI
- Large breaks with two or more different types of debris, including the breaks with the most variety of debris, within the expected ZOI
- Breaks in areas with the most direct path to the sump
- Medium and large breaks with the largest potential particulate debris to insulation ratio by weight, and
- Breaks that generate an amount of fibrous debris that, after its transport to the sump screen, could form a uniform thin bed that could subsequently filter sufficient particulate debris to create a relatively high head loss referred to as the 'thin-bed effect.' The minimum thickness of fibrous debris needed to form a thin bed has typically been estimated at 1/8 inch thick based on the nominal insulation density.

From these break location considerations, the limiting break that resulted in the bounding debris generation was S2. See Figure 2-1, below.

The description of the insulating materials for the reactor vessel is contained in the Turkey Point UFSAR. Per the Turkey Point UFSAR, the reactor vessel insulation is of the reflective type, supported from the nozzles and consisting of inner and outer sheets of stainless steel spaced 3 inches apart. The Reactor Vessel Head permanent insulation (i.e., within the Integrated Head Assembly) for Unit 3 & 4 consists of self supporting panels, constructed of metallic reflective insulation, that are attached to one another with stainless steel buckles.

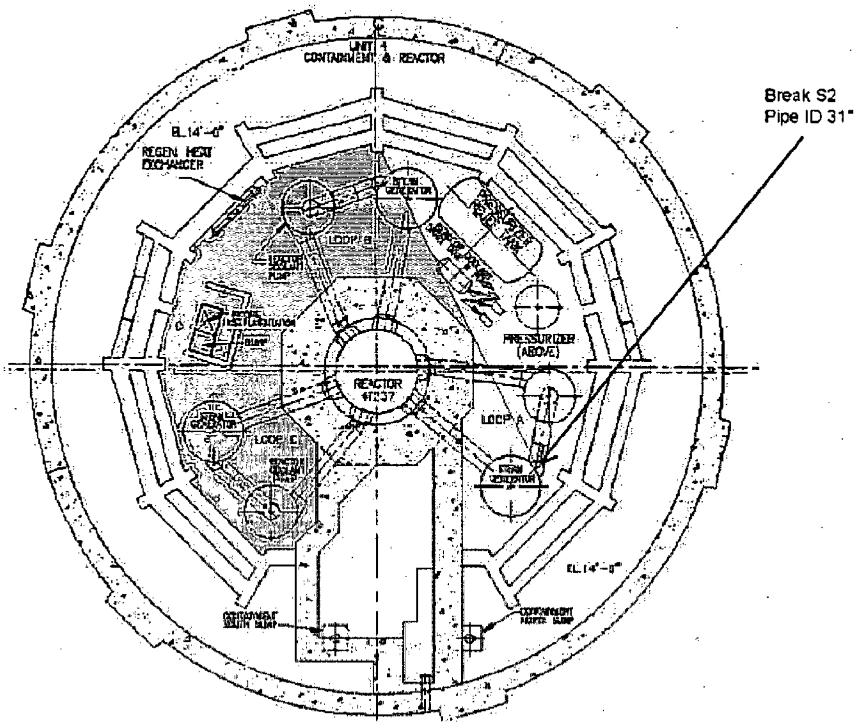


Figure 2-1 Break S2 and Shadow Area

RAI 3

Please provide a description of the jacketing/banding systems used to encapsulate steam generator Nukon insulation at Turkey Point 4 and during the applicable jacketing/banding system qualification testing. The information should include the jacket materials used in the testing, geometries and sizes of the targets and jet nozzle, and materials used for jackets installed on the steam generators. Please provide information that compares the mechanical configuration and sizes of the test targets and jets, and the potential targets and two-phase jets in the plant. Please evaluate how any differences in jet/target sizing and jet impingement angle affect the ability of the insulation system or systems to resist damage from jet impingement. In doing so, please provide a justification for applying debris generation test data obtained for the insulation jacketing systems employed at the Wolf Creek and Callaway reactor plants to the jacketing systems used at Turkey Point 4, demonstrating that the Turkey Point 4 jacketing systems are as resistant to destruction as the jacketing systems tested.

RESPONSE

The Zone of Influence (ZOI) test data determined by the testing performed for the Wolf Creek and Callaway reactor plants is applicable to Turkey Point Unit 4 for the following reasons:

- Test data showed that the NUKON® blankets did not release NUKON® fiber even when the stainless steel lagging was blown off the insulation at a ZOI of 6D with the jet perpendicular to the test article.
- The NUKON® installed at Turkey Point Unit 4 is substantially the same as the NUKON® blankets used during the testing.
- The lagging for the steam generators at Turkey Point Unit 4 is stainless steel, which was also the lagging used during the testing.

- The steam generators at Turkey Point Unit 4 have only four feet of exposed insulation installed below the solid floor at elevation 30'-6". This floor will provide shielding for the vast majority of the generator.
- Testing qualified NUKON® insulation down to a ZOI of 5D but Turkey Point 3 utilized 7D for conservatism.

This is detailed as follows:

The Turkey Point Unit 4 Steam Generator (SG) blanket insulation consists of a quilted, light density, semi-rigid fiberglass (pad) insulation encapsulated with woven glass (cloth) forming a composite blanket. The blanket is single layer insulation of the required thickness to limit the heat transfer to the specified values. The blankets use Velcro type fasteners on the longitudinal seam for ease of installation and removal. The blankets are supplied with stainless steel hooks and nylon loops. The blanket is provided with stainless steel jacket with "Buckle" type fasteners and handles.

The method of installing NUKON® insulation on a steam generator (SG) for Callaway and Wolf Creek differs from the installation of NUKON® on piping. The latches for the SG installation are fabricated from the same types (300 series stainless steel) of materials. The strength of the jacket system for the SG installation is linked to the design for attachment of the panels as described below.

The panels on the steam generators are held on by 4 methods:

- The top of the panel is slid under a piece of metal flashing that is held on by the hitch pins.
- The side of one panel is slid into the S-pocket of an adjacent panel (continues around the equipment piece).
- The bottom of the panel fits over the stainless studs and is secured by the hitch pins.
- A seismic band is placed around the row of panels and uses a piping latch and strike to hold it in place.

Based on a plant-specific evaluation for Callaway and Wolf Creek, direct jet impingement of a jet on the SG panels was evaluated to be excluded based on the configuration of the primary system piping. Rather than impinging on the SG, the jet flow will be parallel to the SG. Thus, jet impingement loading on the SG NUKON® panels is not expected. Thus, the SG panels would not be expected to experience damage to jet impingement.

Five NUKON® fiberglass insulation test articles were included in the test program. These test articles included a length of 8-inch diameter schedule 80 pipe that had the NUKON® insulation material wrapped completely around the pipe. The insulation material consisted of fibrous glass wool wrapped in a fiberglass scrim which, in turn, was contained in a casing of fiber glass cloth. Woven Nomex® Velcro®-type fasteners were attached to the outside of the fiber glass "pillow" containing the fibrous glass wool and fiberglass scrim. The NUKON® insulation was wrapped around a pipe in two separate pieces; an inner layer and an outer layer. The NUKON® pillows were fastened into place using the built-in Velcro® fasteners. A stainless steel jacket was then placed around the NUKON® insulation. The stainless steel jacket was equipped with clasps resembling suitcase latches to secure the jacket around the insulation. The jacketing and clasp configuration tested was equal to the as-installed configuration for the stainless steel jacketed NUKON® insulation on piping at the Callaway and Wolf Creek nuclear plants.

The test stand positioned each of the specimens at elevation such that the centerline of the specimens was perpendicular to the centerline of the nozzle. The lip or overlap resulting from the clasps is the weakest location of the jacketing material as the discontinuity in the jacketing potentially allows for flow to get underneath and lift the jacket. It is noted the text on page II-21 of NRC's SER on NEI 04-07 states:

> ". . . it appeared that a seam orientation of approximately 45 degrees from the oncoming jet maximizes the potential for jacket opening . . ."

but does not distinguish between up or downward. To maximize the potential for the jet flow to get underneath the stainless steel jacketing overlap, the clasps of the jacketing were positioned upward at a 45° angle from the vertical and facing the nozzle. This positioning of the clasps provided for a conservative test of the strength of the jacketing and clasp design.

Table 3-1
Summary of Callaway/Wolf Creek Nuclear Plant Jacketed NUKON® Thermal Insulation Jet Impingement Tests

Fluid Supply Pressure = 2000 psig — Nozzle Size = 3.5 inches
Fluid Supply Temperature = 530°F (nominal target value)

| Test Articles | Equivalent Spherical Zone of Influence (ZOI) (Distance from Jet Nozzle in Test) |
|---|---|
| NUKON® Insulation System (jacketed with latches to secure the jacketing in place) | 13 D<br>(174 inches) |
| NUKON® Insulation System (jacketed with latches to secure the jacketing in place) | 10 D<br>(124.8 inches) |
| NUKON® Insulation System (jacketed with latches to secure the jacketing in place) | 8 D<br>(90 inches) |
| NUKON® Insulation System (jacketed with latches to secure the jacketing in place) | 6 D<br>(58.8 inches) |
| NUKON® Insulation System (jacketed with latches to secure the jacketing in place) | 5 D<br>(43.2 inches) |

The testing clearly demonstrates the acceptability of reducing the ZOI associated with the NUKON® from a spherical-equivalent ZOI of 17D to a value of 5D. However, for conservatism, it was suggested that a 7D ZOI be used for sump design calculations.

Several significant observations are noted from the NUKON® jet impingement tests, particularly those performed at small ZOI values:

1. First, while the stainless steel jacketing definitely protects the underlying NUKON® insulation, the removal of the jacketing material by the impinging jet does not result in the release of fibrous material from the woven fiberglass cloth-covered blanket or "pillow."
2. The direct impingement of the jet on a woven fiberglass cloth-covered blanket or "pillow" did not result in the failure of the woven fiberglass cloth-covered blanket material.

Rather, the fabric stretched but did not release or allow the extrusion of fiberglass enclosed in the woven fiberglass cloth-covered blanket. This survivability of the woven fiberglass cloth-covered blanket was observed to a 5 D ZOI.

3. Small tears in the woven fiberglass cloth-covered blanket, evaluated to result from the movement of jacketing material resulting from forces exerted by jet impingement, did not result in the release or extrusion of the fiberglass material enclosed in the woven fiberglass cloth-covered blanket.
4. The test fixture was designed to represent the as-installed pipe insulation configurations; however, the bracing for the test rig was observed to result in some non-typical damage, but the observed insulation damage did not influence the test results. In only one case, the 5D ZOI test, did the interaction of the sacrificial end-pieces of NUKON® with the test fixture result in the loss of a visually observable amount of fiberglass insulation material from the woven fiberglass cloth-covered pillow.

NUKON® is a generic type of fibrous insulation which, as supplied by Owens Corning, is the same for all NUKON® applications in the nuclear industry, and has been the same for at least 30 years. This includes the fiberglass wool, scrim, and cloth components of the insulation. From a review of plant specific insulation specifications, plant drawing and plant walk downs, the only significant difference between the NUKON® insulation configurations at the sites is the material type used for jacketing. The tests at Wyle Labs used stainless steel metal jacketing.

At Turkey Point Unit 4, older insulation specifications allowed the use of aluminum or stainless steel jacketing material for piping. Therefore, conservatively, the reduced ZOI results of the testing were disallowed for all Unit 4 piping and the full 17D ZOI was considered. The Unit 4 steam generators, however, have been confirmed to have stainless steel jacketed NUKON®. Therefore, test results were used as basis to reduce the ZOI for the Unit 4 SGs.

Callaway and Wolf Creek eliminated consideration of jet impingement on their SG NUKON® panels (according to WCAP-16710) based on an evaluation of parallel jet flow to the SG panels from the postulated break. Turkey Point Unit 4, a Westinghouse NSSS with similarly configured loop piping, conservatively has considered SG insulation in the debris generation total using 7D ZOI based on this testing which used a 45° jacket seam jet approach (rather than parallel flow). The reduced SG ZOI is further supported by the fact the vast majority of the steam generators are shielded from a direct jet impingement by the concrete floor at elevation 30'-6". The concrete floor would shield the direct jet impingement of the SG insulation for all but approximately four feet of the SGs. Additionally, along the vertical height of the 63 ft tall SGs, there are several steel support rings which provide rigid support platforms for the insulation.

## RAI 4

For Nukon and calcium silicate debris, please describe what percentage of the small fines category was divided into individual fines and small pieces for the head loss flume testing that was conducted for the replacement strainer, and provide a technical basis that the quantity of individual fines was prototypical for plant conditions. Please provide the characteristic size of the fine debris of each type of debris (Nukon and calcium silicate). In particular, for fiberglass insulation, the debris size distribution should account for the reduction in the assumed ZOI from 17D to 7D, which exposes the destroyed debris to a higher destruction pressure.

## RESPONSE

For Turkey Point Unit 4 no credit was taken for NUKON® that did not erode into fines or was generated as large pieces that failed to transport; i.e., all of the debris generated was assumed to transport to the debris interceptors. Turkey Point Unit 4 has debris interceptors that are 88% efficient. The total quantity of NUKON® generated as determined by the debris generation calculation was reduced by 88%. This reduced quantity was credited as reaching the strainers in the form of fines held in suspension. During testing NUKON® in the form of fines was used. The fine fibers were mixed with water and stirred with a paint mixer prior to introduction into the test flume. This methodology accounted for the higher destruction pressures at a ZOI of 7D. The reduction in the assumed zone of influence from 17D to 7D for NUKON® was only used for the insulation on the steam generators. The zone of influence for NUKON® on piping remained at 17D.

A fraction of the Cal-Sil, when subject to break flow energy and spray wash-down, erodes into fines that are sufficiently small that the individual fibers or particles stay suspended in the water indefinitely. The fines in suspension were determined to be 35% of the total quantity generated based upon NUREG/CR-6808 and NUREG/CR-6772. These suspended fines will move to the sump at any flow velocity. The remaining fraction of the Cal-Sil forms discrete particles which sink to the bottom of the pool and may be transported by the flow if the velocities equal or exceed the threshold velocity for incipient tumbling of Cal-Sil. The total quantity of Cal-Sil generated was 79.85 ft$^3$ as determined by the debris generation calculation. Of this quantity 49.08 ft$^3$ was determined to reach the strainers by the debris transport calculation. During testing Cal-Sil powder was used. This is a conservative decision that is consistent with NEI 04-07, revision 0, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Volume 1, paragraph 3.4.6, and Table 3-2.

## RAI 5

Please provide a contour plot of the containment pool velocities that includes both the velocities inside the bioshield wall and in the outer annulus. Please also provide a close-up plot of the velocity and turbulence contours in the region of the strainer and its immediate surroundings. Please also provide a table of the head loss test flume (average) velocity as a function of distance from the test strainer and identify the turbulence level simulated in the test flume.

## RESPONSE

The requested contour plots are shown in Figures 5-1 and 5-2 below. Additional turbulence, above that which is associated with the shear in the flow as the water approaches the strainer in the test flume, was not implemented.

The following table and plots depict the test flume (average) velocity as a function of distance from the test strainer. The turbulence level in the test flume is that which is associated with the shear in the flow as the water approaches the strainer in the test flume.

|  | Module A | Module B | Module C |  |  |
|---|---|---|---|---|---|
| Distance from Strainer | Approach Velocity (ft/s) | Approach Velocity (ft/s) | Approach Velocity (ft/s) | Average Velocity (ft/s) | WT AVE (2X Max) (ft/s) |
| 1 | 0.147 | 0.1120 | 0.0923 | 0.1171 | 0.1246 |
| 2 | 0.154 | 0.1033 | 0.0893 | 0.1156 | 0.1252 |
| 3 | 0.178 | 0.0957 | 0.0920 | 0.1219 | 0.1359 |
| 4 | 0.209 | 0.0487 | 0.0830 | 0.1136 | 0.1374 |
| 5 | 0.223 | 0.0737 | 0.0747 | 0.1238 | 0.1486 |
| 6 | 0.249 | 0.1210 | 0.0733 | 0.1478 | 0.1731 |
| 7 | 0.22 | 0.1200 | 0.0823 | 0.1408 | 0.1606 |
| 8 | 0.222 | 0.1440 | 0.1100 | 0.1587 | 0.1745 |
| 9 | 0.224 | 0.1477 | 0.1100 | 0.1606 | 0.1764 |
| 10 | 0.227 | 0.1497 | 0.1287 | 0.1684 | 0.1831 |
| 11 | 0.226 | 0.1420 | 0.1180 | 0.1620 | 0.1780 |
| 12 | 0.227 | 0.1170 | 0.1063 | 0.1501 | 0.1693 |
| 13 | 0.23 | 0.1117 | 0.1037 | 0.1484 | 0.1688 |
| 14 | 0.234 | 0.1230 | 0.1107 | 0.1559 | 0.1754 |
| 15 | 0.237 | 0.1357 | 0.0977 | 0.1568 | 0.1768 |
| 16 | 0.237 | 0.1390 | 0.1190 | 0.1650 | 0.1830 |
| 17 | 0.231 | 0.1553 | 0.1277 | 0.1713 | 0.1863 |
| 18 | 0.229 | 0.1693 | 0.1340 | 0.1774 | 0.1903 |
| 19 | 0.221 | 0.1783 | 0.1223 | 0.1739 | 0.1857 |
| 20 | 0.217 | 0.1747 | 0.0977 | 0.1631 | 0.1766 |
| 21 | 0.22 | 0.1667 | 0.0850 | 0.1572 | 0.1729 |
| 22 | 0.224 | 0.1503 | 0.0907 | 0.1550 | 0.1723 |
| 23 | 0.211 | 0.1363 | 0.0950 | 0.1474 | 0.1633 |
| 24 | 0.231 | 0.1263 | 0.1030 | 0.1534 | 0.1728 |
| 25 | 0.245 | 0.1217 | 0.1093 | 0.1587 | 0.1803 |
| 26 | 0.26 | 0.1393 | 0.1163 | 0.1719 | 0.1939 |
| 27 | 0.256 | 0.1530 | 0.1243 | 0.1778 | 0.1973 |
| 28 | 0.234 | 0.1625 | 0.1277 | 0.1747 | 0.1895 |
| 29 | 0.226 | 0.1668 | 0.1270 | 0.1733 | 0.1864 |
| 30 | 0.221 | 0.1698 | 0.1147 | 0.1685 | 0.1816 |

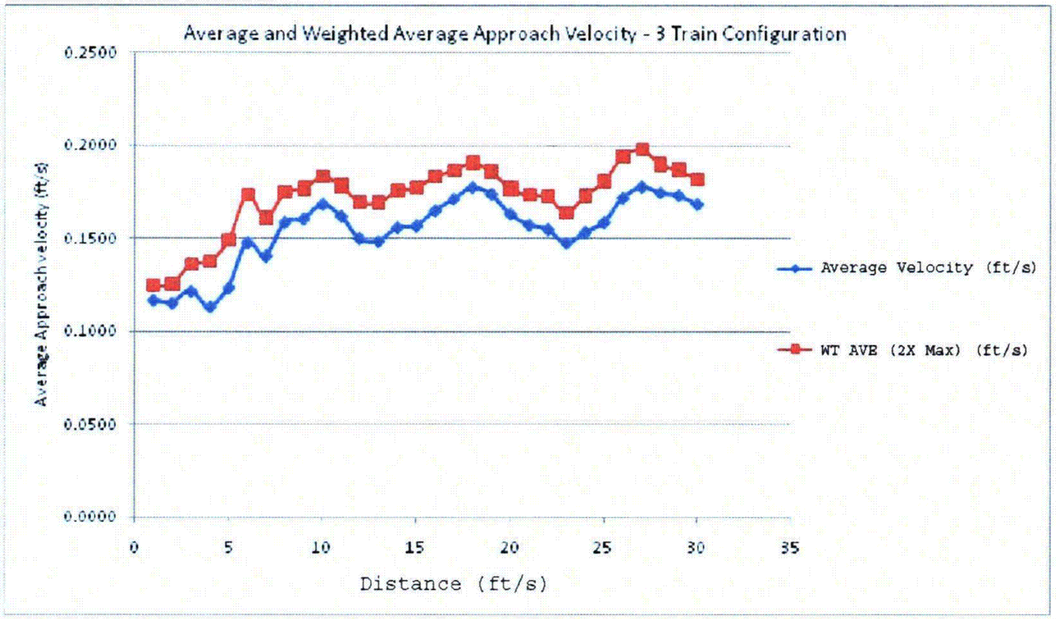


Table 5-1 Approach Velocity

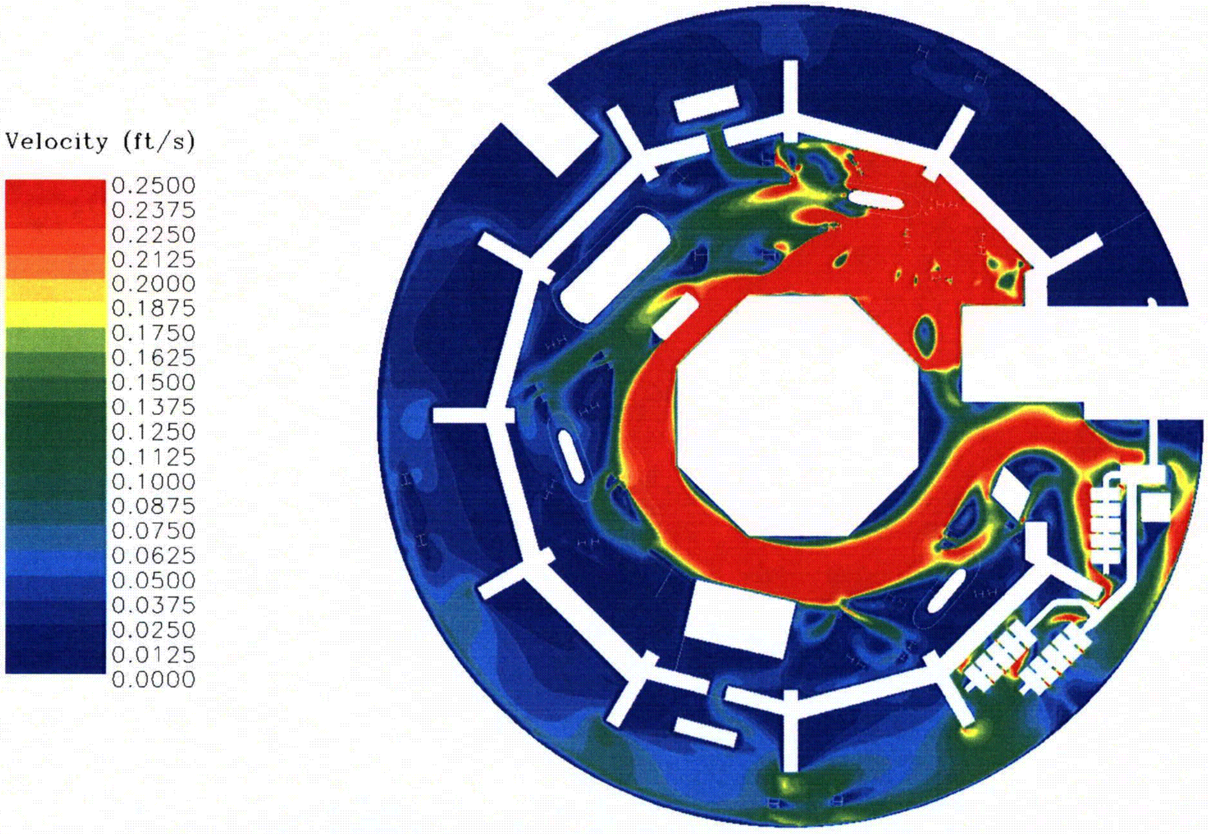


Figure 5-1. Plot of velocity contour at mid-depth

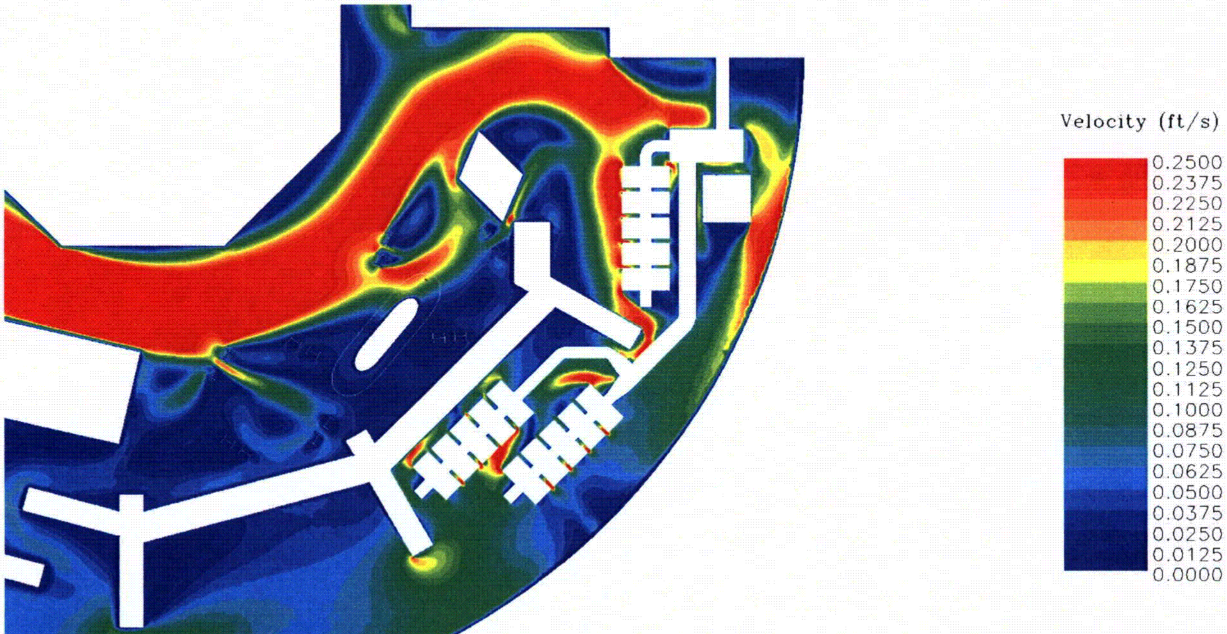


Figure 5-2. Plot of velocity contour within 20 feet of the strainer

RAI 6

Please discuss how erosion of fibrous and calcium silicate debris in the containment pool was addressed and provide technical justification.

RESPONSE

For Turkey Point Unit 4 no credit was taken for NUKON® that did not erode into fines or was generated as large pieces that failed to transport; i.e., all of the debris generated was assumed to transport to the debris interceptors. Turkey Point Unit 4 has debris interceptors that are 88% efficient. The total quantity of NUKON® generated as determined by the debris generation calculation was reduced by 88%. This reduced quantity was credited as reaching the strainers in the form of fines held in suspension. Since the quantities were all assumed to be fines, an erosion factor for NUKON® is not applicable.

A fraction of the Cal-Sil, when subject to break flow energy and spray wash-down, erodes into fines that are sufficiently small that the individual fibers or particles stay suspended in the water indefinitely. The fines in suspension were determined to be 35% of the total quantity generated based upon NUREG/CR-6808 and NUREG/CR-6772. These suspended fines will move to the sump at any flow velocity. The remaining fraction of the Cal-Sil forms discrete particles which sink to the bottom of the pool and may be transported by the flow if the velocities equal or exceed the threshold velocity for incipient tumbling of Cal-Sil. The total quantity of Cal-Sil generated was 79.85 $ft^3$ as determined by the debris generation calculation. Of this quantity, 49.08 $ft^3$ was determined to reach the strainers by the debris transport calculation. During testing Cal-Sil powder was used. As such, greater than 61% of the Cal-Sil generated is assumed to reach the screen and is tested in the flume using Cal-Sil powder.

RAI 6a & 6b

If testing was used to justify any assumptions made concerning erosion, please provide the following additional information:

a. A comparison of the flow conditions (velocity and turbulence), chemical conditions, and fiberglass material present in the erosion tests to the analogous conditions for Turkey Point 4.
b. The duration of the erosion tests and how the results were extrapolated to the sump mission time.

RESPONSE

No testing was performed to justify any assumptions made concerning erosion, beyond the debris testing discussed in NUREG/CR-6808 and NUREG/CR-6772.

RAI 7

Please describe how the kinetic energy of the containment sprays entering the containment pool was modeled. Spray flow splashing into the containment pool can have a significant impact on the velocity and turbulence distributions in the containment pool. Furthermore, the drainage from the containment sprays frequently is not uniform (as is assumed for Turkey Point 4) at the containment pool elevation due to non-uniformities in the structures at higher elevations that can result in concentrated drainage (e.g., refueling canal drains, hatch openings, gaps in curbs, etc.). Please provide the justification for using a uniform spray drainage model.

RESPONSE

The spray flow in general was assumed to fall as discrete drops, representing the disassociation of the water as it falls from the upper levels and its impact on equipment and structures.

Droplets impacting the water surface with terminal velocities approaching that of large raindrops essentially do not penetrate the water surface and the associated small kinetic energy associated with the impact is limited to the regions near the free surface.

Turbulent kinetic energy was specified at the water surface where the water from the sprays is assumed to enter the pool. To set a turbulence level at this inflow location, the turbulence intensity was set to 5% and the turbulent viscosity ratio was set to 5%. A kinetic energy plot is shown in Figure 7-1 below.

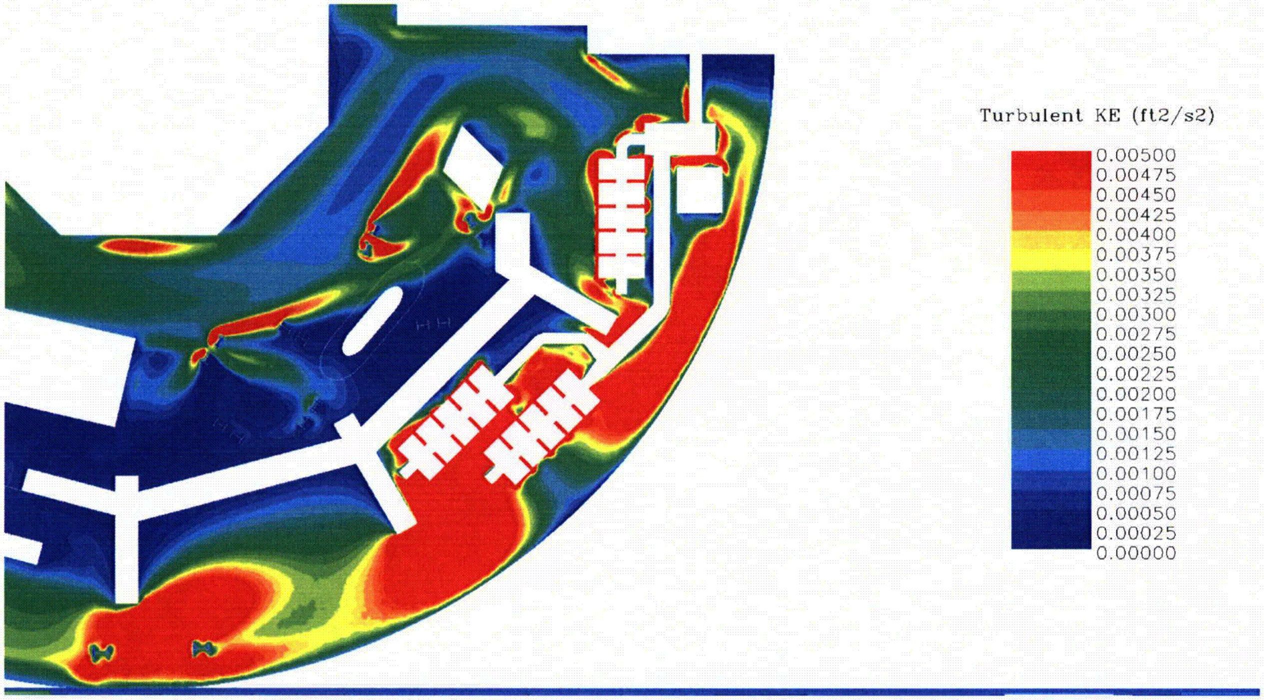


Figure 7-1 Plot of turbulent kinetic energy within 20 feet of the strainer

<u>RAI 8</u>

The August 11, 2008, supplemental response states on page 16 that streamline plots were used to identify isolated eddies that had velocities higher than the incipient tumbling velocity but did not contribute to debris transport from the zone. Please provide the basis for considering debris assumed to be present in this area at the switchover to recirculation to not transport to the strainers, considering the following points:

<u>RAI 8a</u>

Even in steady-state turbulent flow problems, chaotic perturbations result in variance in the solution that will alter the flow pattern in isolated eddies and allow fluid and debris elements in these eddies to escape as time or the number of computational iterations increases. Sophisticated turbulence models are expected to be necessary to accurately predict the behavior of eddies if they are credited with retention of debris. Please discuss the fidelity of the turbulence model used in the computational fluid dynamics code and discuss whether the converged solution was run further and checked at various intervals after convergence was reached to demonstrate evidence of the stability of any eddies credited with debris hold up.

<u>RESPONSE 8a</u>

The areas of recirculation in question only exist for the 0.06 ft/s velocity contours (associated with transport of small fiberglass material) and are identified in Figure 8-1 below. The areas within the recirculation zones represent 0.12% of the total area that transports material to the screens. The material contained in this zone is considered negligible compared to the total amount of material transported to the sump screens.

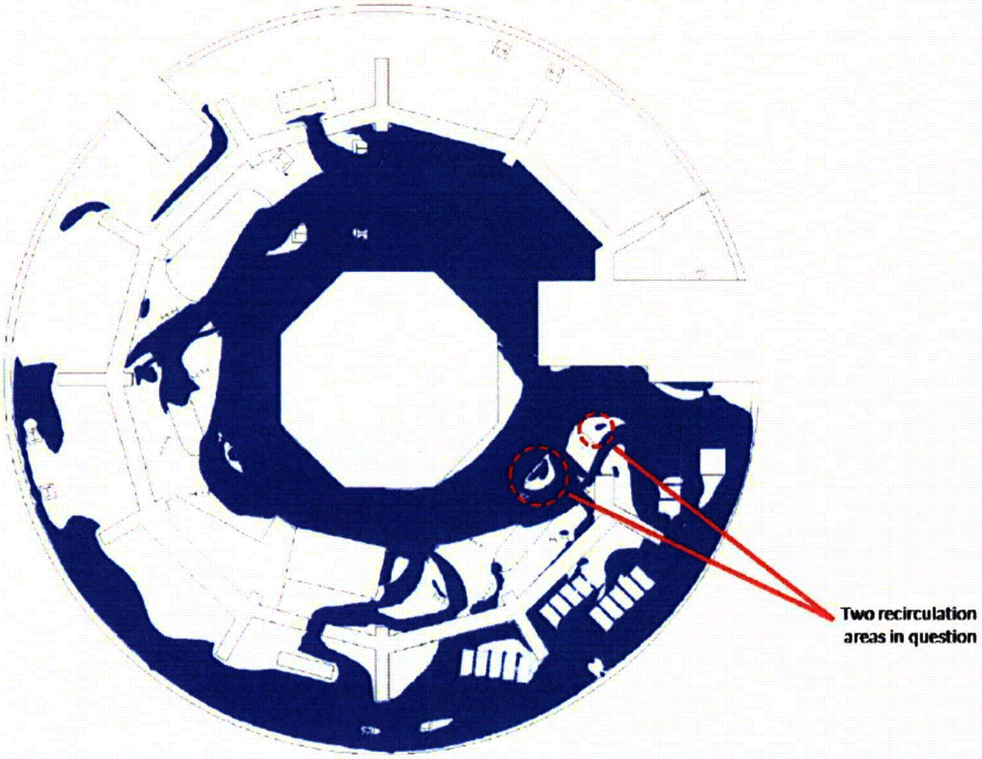


Figure 8-1 Isocontours of Velocity: 6 fps and above

RAI 8b

Suspended debris and floor-transporting debris do not precisely follow streamlines of fluid flow. This phenomenon (phase slip) can be particularly significant when the streamlines exhibit significant curvature, such as in an eddy.

RESPONSE 8b

See Response 8a and Figure 8-1.

RAI 8c

There are significant uncertainties associated with modeling blowdown, washdown, and pool fill transport mechanisms. As a result, the initial debris distribution at switchover can vary significantly.

RESPONSE 8c

The methodology used to model blowdown, washdown, and pool fill transport mechanisms was developed in accordance with NEI-04-07 guidance. The PTN4 containment was divided into proximity zones based on plant configuration and major equipment, which was used to define the location of debris based on blast effects, pool fill effects, and washdown effects. Also see the response to RAI 10.

RAI 9

Please provide the methodology and technical basis for the conclusion that 38 percent of the calcium silicate debris settles in the containment pool. Please state the size distribution of the calcium silicate that is assumed to settle in the containment pool.

RESPONSE

A fraction of the Cal-Sil, when subject to break flow energy and spray wash-down, erodes into fines that are sufficiently small that the individual fibers or particles stay suspended in the water indefinitely. The fines in suspension were determined to be 35% of the total quantity generated based upon NUREG/CR-6808 and NUREG/CR-6772. These suspended fines will move to the sump at any flow velocity. The remaining fraction of the Cal-Sil forms discreet particles which sink to the bottom of the pool and may be transported by the flow if the velocities equal or exceed the threshold velocity for incipient tumbling of Cal-Sil (0.25 ft/sec).

The debris transport analysis calculated that 49.08 $ft^3$ of Cal-Sil will transport to the sump strainer screen from the various zones around containment following the limiting break S2. The two tables below detail the Cal-Sil distribution in the various zones considered:

Table 9-1
Debris Transport Amount

| | Zone 101 | Zone 102 | Zone 103 | Zone 104 | Zone 105 | Zone 106 | Zone 107 |
|---|---|---|---|---|---|---|---|
| Cal-Sil $ft^3$ (Small) | 2.45 | 2.52 | 32.78 | 0.00 | 2.79 | 2.32 | 1.46 |
| Cal-Sil $ft^3$ (Large) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 9-1 continued
Debris Transport Amount

| | Zone 108 | Zone 109 | Zone 110 | Zone 111 | 58 ft (1/3) | 58 ft (2/3) | Inactive | Total* |
|---|---|---|---|---|---|---|---|---|
| Cal-Sil $ft^3$ (Small) | 0.37 | 0.95 | 1.08 | 0.39 | 1.30 | 0.68 | 0.00 | 49.08 |
| Cal-Sil $ft^3$ (Large) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

* The calculated value of Cal-Sil shown reflects the resultant value with the appropriate rounding techniques employed.

The total transported Cal-Sil (49.08 $ft^3$) is a portion of the total Cal-Sil generated from the S2 Break (79.85 $ft^3$). As stated in the RAI, these values result in the conclusion that 38% of the Cal-Sil debris fails to transport or remains in suspension in the inactive containment pool. The calculation of the amount of Cal-Sil that would transport is based upon industry guidelines in NEI 04-07 and the NRC Safety Evaluation Report of NEI 04-07. The following outline presents the general methodology for performing the debris transport calculations for the Turkey Point Unit 4 containment following a Loss of Coolant Accident (LOCA).

1. Perform steady state computational fluid dynamic (CFD) simulation for a given break scenario.
2. Post-process the CFD results by plotting 3D surfaces of constant velocity. These velocities will correspond to the incipient transport velocities tabulated in NEI 04-07 for the debris generated in the LOCA scenario.

3. Project the extent of these 3D surfaces of velocity onto a horizontal plane to form a flat contour. Automatically digitize a closed curve around the projected velocity contour and calculate the area within the curve.
4. Compare the area calculated in 3 (above) to the total floor area of the zone containing the particular debris type/size under consideration. This comparison gives the fraction of the floor area susceptible to transport.
5. Tabulate the results of each calculation to determine the total fraction of debris transported to the sump for each LOCA break scenario and each debris type.

RAI 10

The transport assumptions for blowdown, washdown, and pool fill up can significantly affect the debris transport fractions for Turkey Point 4 due to the installation of the debris interceptors at the exits to the bioshield wall. Little information was provided in these areas in the supplemental responses. Please summarize the transport analysis methodology and results for the blowdown, washdown and pool fill up transport processes for all types of debris, and identify the resulting debris distribution in the containment pool assumed at the initiation of sump recirculation.

RESPONSE

The methodology used in the analysis was developed using the guidance contained in NEI 04-07 volumes 1 and 2.

The Turkey Point debris transportation calculation developed the transportation logic for large and small debris associated with the Turkey Point break designated as "S2" worst case break location. Containment elevations 14', 30'-6", and 58' were divided into proximity zones based on general plant configuration and major equipment. The proximity zones were used to define the location of debris based on blast effects, pool fill effects, and wash down effects.

Small Debris Distribution due to Blast and Pool Fill

It was assumed that 50% of the small debris generated by break S2 would remain evenly distributed in proximity zone 103 at the end of blast and pool.

30% of the small debris was assumed to transport horizontally out and be evenly distributed on elevation 14' inside the secondary bioshield wall.

20% of the small debris was assumed to transport vertically and horizontally based on the ratio of the individual passage opening area to the total area of all passages.

The debris transport fractions for small debris due to blast and pool fill are summarized in the distribution logic tree provided below. At the onset of containment sump recirculation all debris was assumed to be evenly distributed in the end proximity zone as defined by the transport logic. In addition debris within the secondary bioshield on the 14' elevation was subjected to inactive sump debris sequestering. Inactive sump debris sequestering is discussed below.

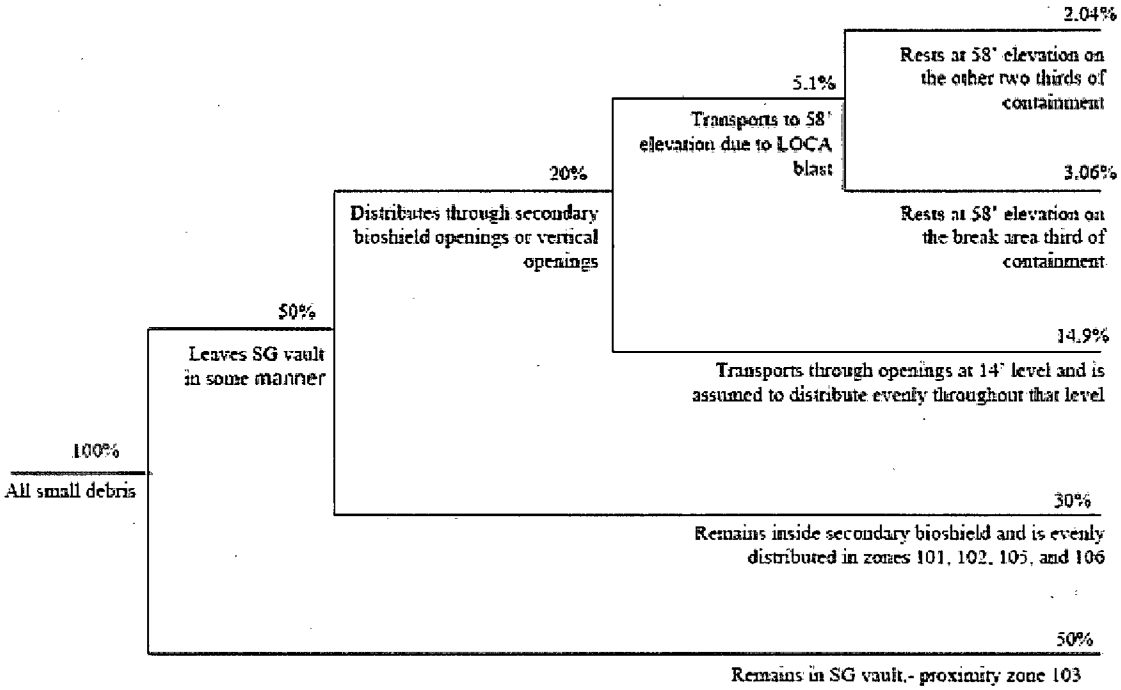


Figure 10-1 Distribution Logic For Small-Sized Debris
That Originates In Proximity Zone 103 Through Blowdown and Pool Fill Transport

Large Debris Distribution due to Blast and Pool Fill

It was assumed that 85% of the large debris generated was subject to transportation effects due to blast and pool fill effects, and that 15% was not subject to transport and remained in the break location, proximity zone 103. The large debris was assumed to transport based on the ratio of the lengths of each opening in the walls within proximity zone 103 as compared to the total length of the walls and total length of the wall openings.

Based on the methodology provided above, a large debris logic tree was developed and is presented below. All large debris was assumed to be evenly distributed in the break room (proximity zone 103) and proximity zones 102 and 104 based on the percentages defined by the transport logic below.

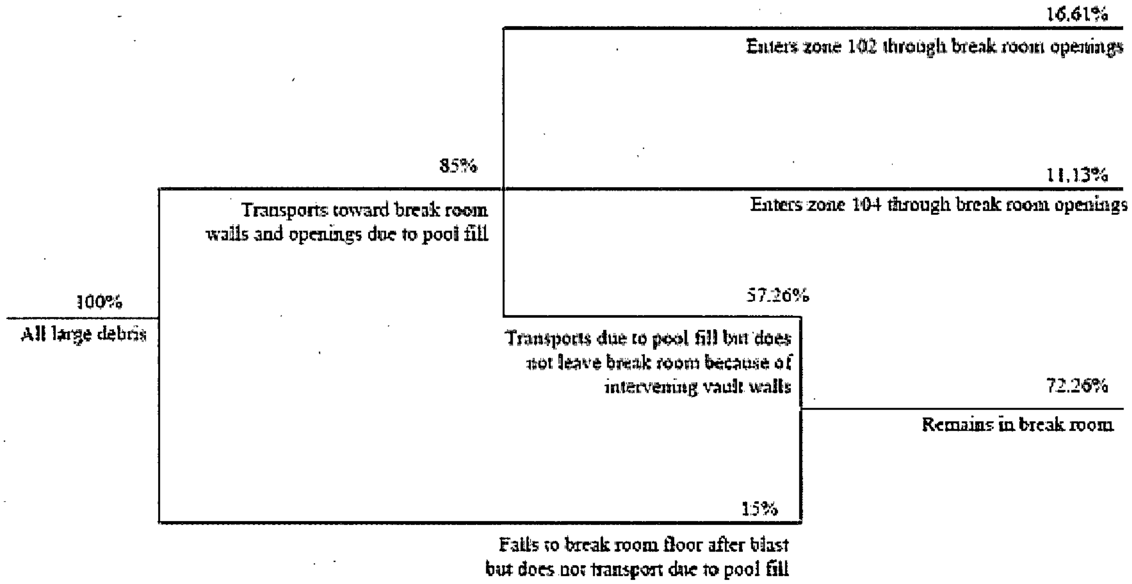


Figure 10-2: Distribution Logic For Large Debris
That Originates In Proximity Zone 103 Through Blast and Pool Fill Transport

Inactive Sump Debris Sequestration
All debris that is subject to sequestration is also considered highly transportable during all phases of debris transport before recirculation. Therefore, two steps are taken with regards to the reduction of the quantity of small debris that may reach the ECCS recirculation sump.

First, there is the method that is consistent with the NEI 04-07 Baseline Methodology approach, where all small debris is assumed transportable to the ECCS recirculation sump as well as the inactive sumps during blowdown, washdown, and pool fill transport. In this case, the percentage of the total pool volume that is within the inactive sump is used to reduce all small debris including latent and miscellaneous debris, and failed coatings.

The second approach considers how the small debris is trapped in the inactive sump and what percentage of the 4" x 4" small debris will transport. This builds on the analytical refinement available with the use of the computational fluid dynamics (CFD) model. This calculation provides the amount of debris generated and distributed during the LOCA blast. The debris that ends up somewhere on the lowest elevation is transported by pool fill effects away from the break location. The debris that ends up on the upper levels is assumed to washdown completely through the available openings to the proximity zones outside the secondary bioshield. In addition, it was determined how much of the small debris will remain suspended in the pool and remain fully transportable. Furthermore, the debris that ends up outside the secondary bioshield will remain there and prevent it from becoming sequestered in the inactive sump. Therefore, the only small insulation debris that will end up trapped in the inactive sump is that which remains within the secondary bioshield along with the latent and miscellaneous debris, and failed coatings.

The significant inactive sump (containment sump and reactor cavity access tunnel) volume for

PTN4 is calculated to be 7,041.25 $ft^3$. This value was then divided by the total containment sump volume to determine what percentage of the containment sump was inactive, in this case 22%. Based on NEI guidance, 15% of the debris was sequestered in the inactive sump volume, which is conservative based on the calculated 22% for PTN4.

Debris Distribution due to Washdown
The debris transport calculation utilized settling and incipient tumbling velocities to determine the amount of debris that washed down due to containment spray. A computational fluid dynamics (CFD) simulation was utilized to develop velocity isosurfaces and streamline plots to predict debris transport due to washdown and containment sump recirculation.

RAI 11
The supplemental response did not provide sufficient information concerning the debris interceptors to justify the credit apparently assumed for fibrous debris capture at the interceptors. Please provide the following information concerning the debris interceptors:

RAI 11a
The assumed capture efficiency for fibrous debris.

RESPONSE
The debris interceptor capture efficiency was conservatively determined to be approximately 88%, based on the results of the highest bypass fraction tested (11.3%).

RAI 11b
The interceptor screen perforation size.

RESPONSE
The debris interceptor (DI) used during the PTN-4 debris interceptor test had a vertical section and a top shelf (horizontal section) which had a 3/8" SS wire cloth on the upstream side of both sections. The upstream side of the debris interceptor consisted of 1" x 3/16" grating.

RAI 11c
The interceptor height.

RESPONSE
The installed debris interceptors are mounted to supporting posts and the bioshield walls. The heights of the posts are 23, 34, and 35 inches tall, depending on location. The installed debris interceptor height is fixed at approximately 33 ¼ inches (33 ½ inches maximum). The test DI height was 32 inches.

RAI 11d
The dimensions of the interceptor roof.

RESPONSE
The dimensions of the roof of the test debris interceptor were 25" x 19". The roof area is 475 square inches. The installed debris interceptors are of various lengths between approximately 35 inches and 50 inches with a nominal width of approximately 19 inches. The installed debris interceptors (DIs) are designated as Bio-Wall Left, Bio-Wall-Right, and Fuel Transfer Canal. The total installed DI roof area is approximately 9000 square inches (see Figure 11-1 below).

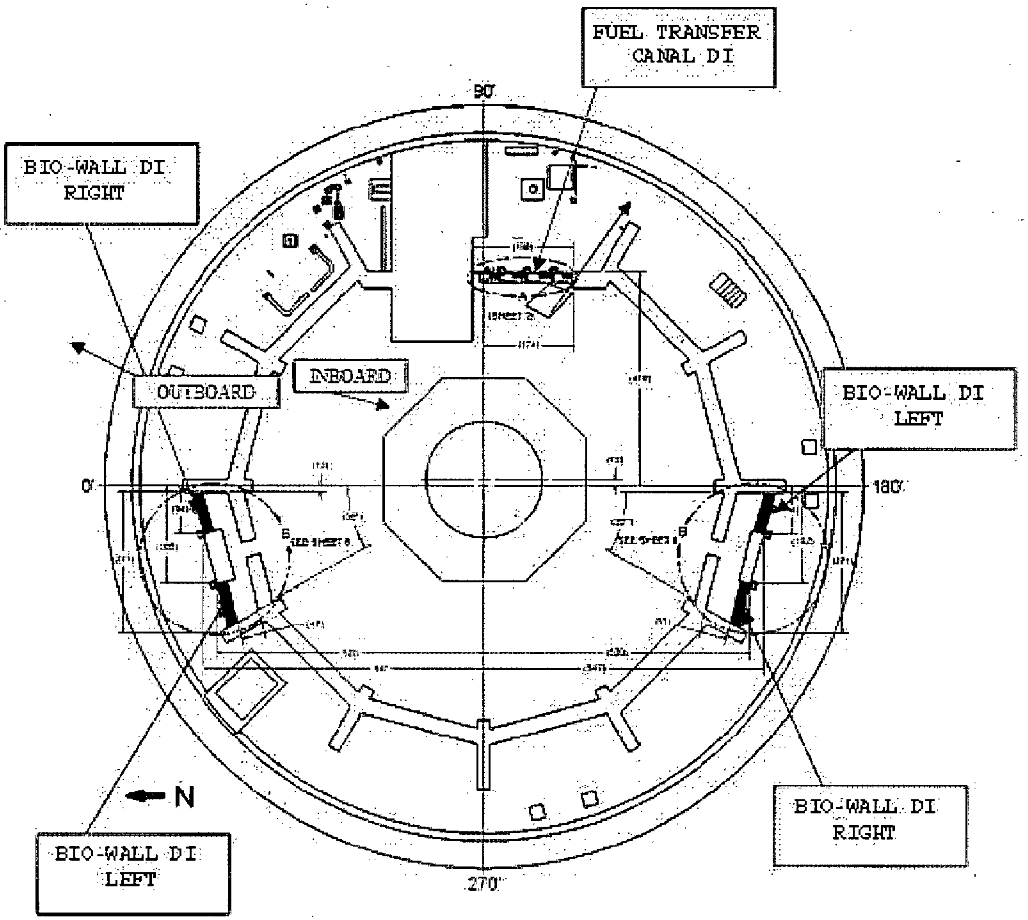


Figure 11-1 Turkey Point Unit 4 Debris Interceptor System

<u>RAI 11e</u>
The total surface area of the interceptors.

<u>RESPONSE</u>
The total surface area of the installed interceptors is approximately 17,000 square inches. This is the area of the vertical screen. The test interceptor was a prototypical section of the PTN -4 debris interceptors with a total surface vertical screen area of 800 square inches.

<u>RAI 11f</u>
The characteristic size and size distribution of all debris used for the testing of the interceptors.

<u>RESPONSE</u>
The debris size category percentages for the NUKON® insulation is 8% fines, 25% small pieces, 32% large pieces and 35% remaining intact. This is consistent with NEI 04-07 guidance. A 10% erosion factor was included for small and large piece into fines. The foreign material fibrous quantity was assumed to be 100% fines.

RAI 11g
A summary of any analysis done to assess debris floatation over the interceptors.

RESPONSE
No analysis was done to assess debris floatation over the debris interceptors, but observations were made during testing. A test was performed in which all of the fibrous debris transported to the debris interceptor (this test was determined to be prototypical), and it was noted that there was a minimal amount of floating debris upstream of the debris interceptor. No further observations of this floating fiber were performed.

RAI 11h
A description of any flowpaths by which fluid in the containment pool inside the bioshield may bypass the debris interceptors.

RESPONSE
There is not a flow path by which the fluid in the pool inside the bioshield may bypass the debris interceptors.

RAI 11i
A summary of any scaling that was done to apply interceptor test results to plant conditions.

RESPONSE
A ratio between the affected PTN4 plant debris interceptor area and the Test debris interceptor area was used to scale the debris loads used during PTN4 debris interceptor testing. A scaling factor of 13.85% was calculated.

RAI 12
Given the credit for the debris interceptors, it is unclear that performing a CFD simulation for only one break provides a sufficient basis to identify the limiting debris loading at the strainers. Please provide the basis for concluding that higher debris transport fractions associated with other postulated breaks would not ultimately result in a more limiting debris loading for the strainers. For example, breaks near the interceptors and/or outside the bioshield wall (if such breaks exist that could require sump recirculation for mitigation) could have much higher transport fractions than the single break analyzed with CFD.

RESPONSE
See the responses to RAI 11. The limiting break location is S2. This break location was conservatively chosen to maximize the amount of debris generated and the close proximity to the strainers.

RAI 13
Please provide the clean strainer head loss (CSHL) calculation methodology. Note that the Performance Contracting, Incorporated (PCI) correlation has not been accepted for application to the pressurized-water reactor (PWR) strainers. The staff is awaiting additional information from PCI after having reviewed certain PCI-provided CSHL test data.

RESPONSE
PCI has prepared Technical Document No. SFSS-TD-2007-002, Revision 1, December 11, 2008, *Sure-Flow® Suction Strainer – Suction Flow Control Device (SFCD) Principles and Clean*

*Strainer Head Loss Design Procedures*. Please note that the original issue (i.e., Revision 0) of the subject document was officially sent to the Staff as a proprietary document in 2007.

The subject Technical Document provides the basis for and design principles associated with the patented suction flow control device (SFCD) also referred to as the core tube. The SFCD has as its primary design function, the ability to achieve a uniform and very low approach velocity to the entire surface of the Sure-Flow® Suction Strainer. The uniform and very low approach velocity serve to ensure that debris reaching the strainer is not affected by high velocity flow that could significantly deposit and pack the post-LOCA debris on the strainer surface areas. Due to the uniform and very low approach velocity associated with the strainer design, issues such as bore holes, vortex formation, unequal debris loading that invalidates the use of temperature correction, and the 'zipper effect' of debris deposit, among others, are not issues for the Sure-Flow® Suction Strainer.

Revision 0 of the subject Technical Document did not provide a sufficient level of detail to address Staff comments and issues. However, Revision 1 of the subject Technical Document has been extensively revised to address the Staff's comments and issues. In addition to specifically addressing Staff concerns, PCI has also provided PWR test data obtained during plant specific testing at the Alden Research Laboratory (ARL).

The following should be noted with regard to the subject Technical Document:

- PCI has used the term 'correlation' and 'Regression Formula' interchangeably in various documents including the subject Technical Document. However, in both cases, the term means the same thing, that is, the clean strainer head loss (CSHL) formula developed by PCI utilizing the Prototype I and II strainers during various testing programs sponsored by PCI at the Fairbanks – Morse Pump Company (FMPCo) and confirmed by testing at the EPRI NDE Center in Charlotte, NC as part of a joint BWROG/EPRI program in 1995 and 1996. The formula is *specifically for and limited* to the PCI patented Sure-Flow® Suction Strainer (SFSS). It does not include interconnecting piping, plenums, fittings, etc. These items are separately addressed by conventional hydraulic and fluid mechanic calculations to establish the CSHL for the entire plant specific strainer arrangement.

  The proprietary PCI Technical Document provides further details regarding the development of the Regression Formula and the testing programs at the Fairbanks Morse Pump Company and the EPRI NDE Center in Charlotte that supported it.

- During the Staff audit of a Licensee in December 2006, a member of the Staff had three questions and related concerns regarding the PCI Regression Formula and its application to calculating the CSHL. One of Staff member's concerns during the audit was that the formula was based on a strainer configuration (i.e., round disk - BWR) that was not similar to that of the Prairie Island SFSS (i.e., square disk - PWR). The Staff member also believed that the Prototype I & II strainers did not have an annulus that 'interconnected' the flow from the strainer disks before the flow entered the core tube slots. Because of the Staff member's belief, they had incorrectly assumed that the Prototype I & II strainer configurations were different than that of the Prairie Island SFSS. Accordingly, the Staff member concluded that the PCI formula for CSHL was not applicable to PWR SFSS configurations. It should be noted that all PCI SFSS configurations for both BWR and PWR plants utilize an annulus in their design which is consistent with the configuration of the Prototype I & II strainers that were utilized to establish the PCI 'Regression Formula'. This fact is documented in the design drawings for both the Prototype I & II strainers as well as those for the Prairie Island SFSS in addition to the other SFSS BWR and PWR plants. Finally, the Staff member also believed that since some of the SFSS module configurations utilized a solid or perforated plate end cap that the flow through the module core tube was affected which in turn also affected the SFSS module CSHL. PCI performed testing at ARL that confirmed that this is not the case. The subject PCI Technical Document addresses all three of the Staff member's questions and concerns:

1. The Regression Formula is applicable and appropriate for both BWR and PWR plants. In all cases where PCI has calculated the strainer module CSHL using the Regression Formula, actual testing at EPRI, FMPCo, and ARL (Alden Research Laboratory) have clearly shown that the Regression Formula is conservative and bounds the actual test results. In other words, the Regression Formula is conservative and provides results that 'over-estimate' the strainer module CSHL when compared to actual test results.

2. All PCI SFSS modules have an annulus that assists in 'balancing' the flow between module disks resulting in uniform flow that results in low CSHL values.

3. There is very little difference between those SFSS strainer module configurations that have either a solid or perforated plate end cap. A solid or perforated plate end cap does not significantly affect the SFSS CSHL values.

- PCI fully recognizes that each SFSS configuration is unique and different due to plant specific requirements and Design Basis parameters. Therefore, PCI 'adjusts' each plant specific strainer to ensure that the total clean strainer head loss is correctly calculated. The PCI formula calculates the CSHL of the strainer core tube. The specific strainer disk configuration including strainer overall length (i.e., module length and number of modules), disk support wires, disk wire flow path, and perforated plate opening size are separately addressed via conventional hydraulic and fluid mechanic calculations that are included as a part of the Total CSHL calculation. The strainer connecting piping and fittings, or collection plenum is addressed in a similar manner by the application of conventional hydraulic calculation applications and methodology.

RAI 14

Please provide verification that the vortex testing was conducted at prototypical or conservative flow rates and physical conditions for the limiting strainer module (e.g. test flume geometry versus plant sump geometry).

RESPONSE

During PTN4 strainer testing it was visually observed that no vortexing occurred around the strainer module in Test 2 and Test 6 (Design Basis Tests). Based on observations made in Test 2, the water level was dropped 2-3 inches below the top perforated strainer plate and no vortexing was observed around the strainer module. Vortexing did not occur in Test 6 as the water level was dropped to the top of the perforated strainer plate. Visual observations during debris introduction and after the max debris load were introduced into the test flume indicated no vortexing occurred.

RAI 15
Please provide documentation of the testing methodology. In general, provide a description of each head loss test run which was instrumental in determining the limiting head loss for the Turkey Point 4 strainer. Please include the purpose of each such salient test, and a description of the steps performed during the test or tests.

RESPONSE
During March 2008, qualification testing of a PCI Sure-Flow® strainer module for Turkey Point Unit 4 was performed . Tests which were instrumental in determining the limiting head loss for the Turkey Point 4 strainer were: the Debris Transport Tests and the Design Basis Tests. The debris transport tests were instrumental because they proved that miscellaneous debris would settle and not transport to the strainer module, while the design basis tests were instrumental because maximum head loss was measured across the strainer module when the design quantity of fibrous, particulate, and chemical debris loads were introduced into the test flume. The results of the tests were used to determine the limiting head loss.

Figure 15-1 Debris Transport Test – Debris for strainer assemblies

Design Basis Debris Loaded Head Loss Test
The purpose of the strainer assembly design basis test was to qualify the PTN4 strainer module for the maximum measured head loss through the strainer module.

RAI 15a
Please include: Debris introduction sequences for each debris type and size, including time between additions and quantities for each test.

RESPONSE
The debris introduction sequences and quantities for each debris type are summarized below.

Latent Fiber The first debris batch was introduced along the entire length of the test flume prior to turning on the recirculation pump and consisted of 25% of the latent fibrous debris (0.30 lbm). Fine NUKON® fiber was used for latent fibrous debris. Five minutes after the introduction of the latent fibrous debris was completed, the recirculation pump was turned on and the flow was set to the design flow rate of 257.2 gpm (0% -- 5%).

Fine Particulate Fine particulate debris was introduced following the latent fiber. Once the design flow rate was obtained, Batch 2 was introduced into the test flume. Batch 2 consisted of 49.85 lbm of Cal-Sil. There were approximately 8 minutes between the completion of Batch 2 and the start of Batch 3. Batch 3 consisted of 49.0 lbm of Tin fine powder. There were approximately 8 minutes between the completion of Batch 3 and the start of Batch 4. Batch 4 consisted of 9.55 lbm of PCI mix Dirt and Dust. There were approximately 8 minutes between the completion of Batch 4 and the start of Batch 5. Batch 5 consisted of 44.85 lbm of walnut shell powder. Batch 5 concluded the introduction of fine particulate debris into the test flume.

Fine Fiber There were approximately 8 minutes between the completion of Batch 5 and the start of Batch 6. Batch 6 consisted of 7.45 lbm of NUKON® fine fiber. Batch 6 concluded the introduction of fine fibrous debris into the test flume.

Chemical Debris (Aluminum Oxyhydroxide – AlOOH) There were approximately 2 hours and 7 minutes between the completion of Batch 6 and the start of chemical debris introductions (Batch 7 – Batch 59). A total of ~144.84 lbm of AlOOH, at a concentration of 11 g/L, was generated per the WCAP-15630 methodology. There were approximately 16 minutes between each batch of chemical debris introduced into the test flume.

Additional Fine Fiber Prior to test termination, an additional 1 lbm of fine NUKON® fiber (Batch 60) was added to the test flume. There were approximately 2 hours and 20 minutes between the completion of Batch 59 (last AlOOH introduction) and the start of Batch 60.

RAI 15b
Please include: The general procedure for conducting the tests.

RESPONSE
The general procedure for conducting the Design Basis Test is summarized below:

- 25% of the latent fibrous debris is introduced through the length of the test flume with the pump turned off for 5 minutes
- The pump is turned on and the design flow rate is achieved in the test flume
- All fine particulate debris is introduced into the test flume upstream of the strainer module
- Following the fine particulate, the fine fibrous debris is introduced into the test flume upstream of the strainer module
- Once all of the fine particulate and fibrous debris is introduced into the test flume, at least five flume turnovers are required between the non-chemical and chemical debris introductions. The chemical surrogate is pumped into the test flume with at least two flume turnovers between batches.

RAI 15c
Please include: Debris introduction locations in the test flume, and the amount of each debris surrogate added to each test.

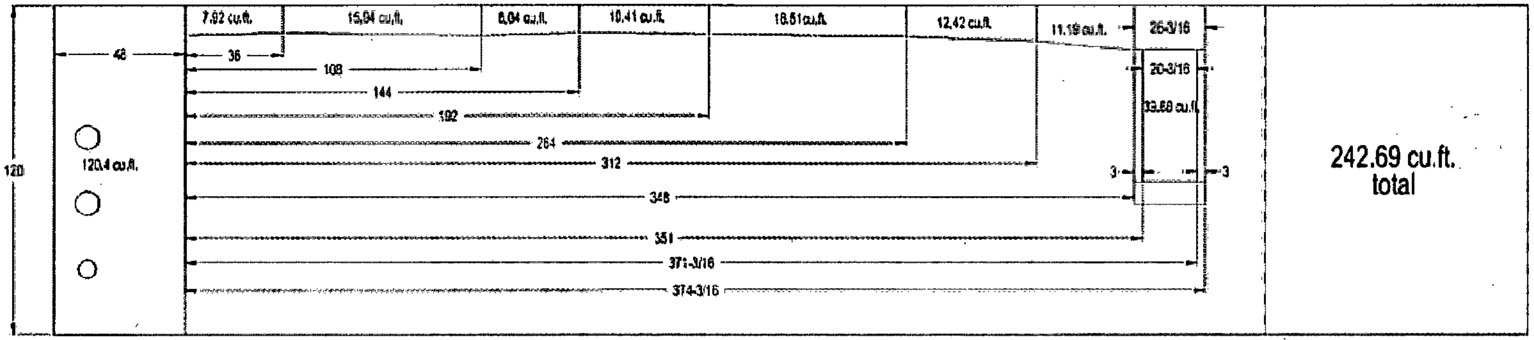
RESPONSE

All debris types with the exception of the first batch (25% of the latent fiber) were introduced into the test flume at the drop zone. Figure 15-2, below, provides the flume wall configuration, with the drop zone for non-chemical and chemical debris labeled. From Figure 15-2, the drop zone is ~350 inches upstream of the strainer module. Batch 1 (25% latent fiber) was introduced uniformly throughout the length of the test flume. The debris amounts that were weighed and introduced into the test flume are presented in Table 15-1 below.

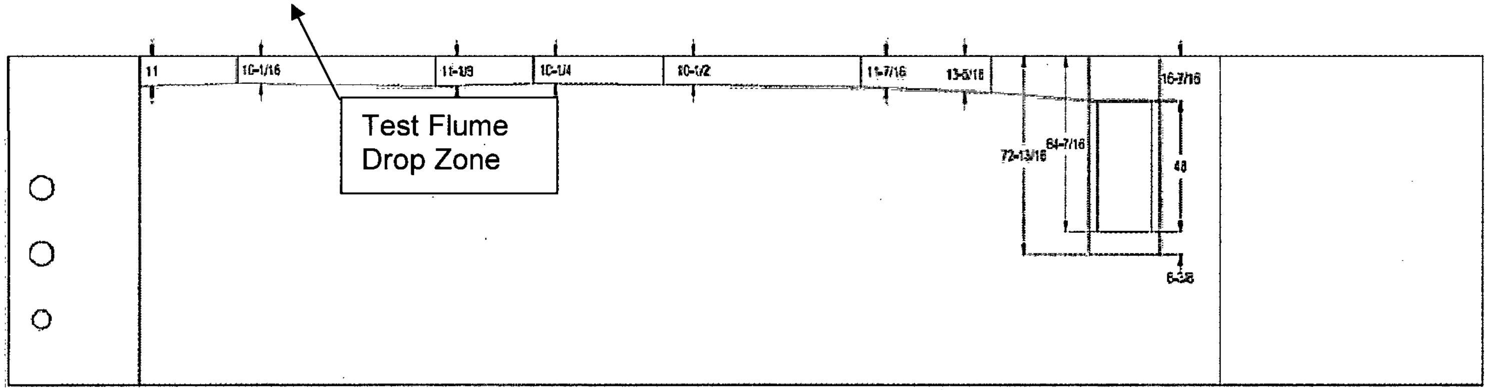
Table 15-1 Design Basis Debris Quantities for Three Strainer Assemblies

| Debris Type | Weighed Amount (lbm) |
|---|---|
| 25% Latent Fiber (Fine NUKON®) | 0.30 |
| Fine NUKON® Fiber | 7.45 |
| Cal-Sil | 49.85 |
| Dirt & Dust | 9.55 |
| Walnut Shell Powder | 44.85 |
| Tin Powder | 49.00 |
| Aluminum Oxyhydroxide* | 144.84 |

* Aluminum Oxyhydroxide in lieu of Sodium Aluminum Silicate



Lengthwise Dimensions



Widthwise and Angular Dimensions

NOTE: ALL UNITS ARE IN INCHES

Figure 15-2 Test Flume Configuration

RAI 15d

Please include: The fibrous debris size distribution with a comparison to transport evaluation predictions of fibrous debris sizes showing that non-prototypical fiber sizes were not added to the test. [Please note that for head loss testing and transport evaluations the categories of small fines and large pieces may not provide sizing that will adequately predict behavior. In general, small fines should be divided further into small pieces and fines.]

RESPONSE

The debris transport for fibrous debris was not used for PTN4 strainer testing; however, a more conservative approach was taken as discussed below. The quantity of material scaled for the flume test is shown in Table 15-2 and Table 15-3, with clarifications as noted:

Table 15-2 Summary of PTN Unit 4 LOCA Generated Debris

| DEBRIS TYPE | BREAK QUANTITY | NOTES |
|---|---|---|
| NUKON® Insulation, Total | 644.37 ft$^3$ | Note (a) |
| | | |
| Cal-Sil Insulation, Piping | 79.85 ft$^3$ | Note (b) |
| | | |
| Mirror RMI, Piping | 8716.93 ft$^2$ | |
| | | |
| Darchem/Transco RMI, Piping/Equipment | 3033 ft$^2$ | |
| | | |
| Qualified Coatings, Total, Steel & Concrete (4.0 D) | 4.0 ft$^3$ total | 2.9 ft$^3$ concrete;<br>1.1 ft$^3$ steel |
| Unqualified Coatings | 5.06 ft$^3$ | |
| Latent Debris (15% fiber, 85% particulate) | 154.44 lbm | Note (c) |
| Foreign Materials | | |
| Labels, Stickers, Tape, Placards, Tags | 44.5 ft$^2$ | |
| Glass | 72.0 ft$^2$ | |
| Adhesives | .03 ft$^3$ | |
| Total (excluding adhesives) | 116.5 ft$^2$ | |
| Insulation Jacketing | | |
| RCS Mirror | 3411.24 ft$^2$ | |
| RCS Darchem/Transco | 2607.47 ft$^2$ | |

Notes:

(a) The maximum NUKON® insulation fiber debris volumes are 315 ft$^3$ (based on a 5D ZOI). Numbers were derived by changing the ZOI (for equipment insulation only) and adding an extra 10% for conservatism. Both of these generated volumes are subject to the debris interceptor retention fraction of 88%. Therefore, the amount of NUKON® insulation scaled for the flume test is 37.8 ft$^3$ (7D, i.e. 315 * 12%) and 29.5 ft$^3$ (5D, i.e. 246 * 12%), all assumed to be fines.

(b) The maximum Cal-Sil insulation debris volume generated is 79.85 ft$^3$, of which 49.08 ft$^3$ is predicted to transport to the sump screens.

(c) The amount of latent debris assumed in the PTN4 containment was 154.44 lbm, of which 15% was fiber and 85% was particulate. This resulted in a latent fiber debris load of 23.2 lbs. A 50/50% split (inside biowall vs. outside biowall) was assumed, with the inside the biowall fiber portion being subject to the debris interceptor retention fraction of 88%. Therefore, the amount of latent fiber debris scaled for the flume test is 13 lbs (i.e. (23.2 * 1/2 * 12%) + (23.2 * 1/2)). The total amount of latent particulate was scaled for the flume test conservatively; i.e., no retention of the latent particulate from the debris interceptors was credited.

Table 15-3
Summary of PTN4 LOCA-Generated Chemicals

| PRECIPITATE | QUANTITY |
|---|---|
| $NaAlSi_3O_8$ | 421.9 Kg |
| AlOOH | 99.9 Kg |
| $Ca_3(PO_4)_2$ | 0 Kg |
| Total | 521.8 Kg |

RAI 15e
Please include: A verification that the amount of fine fiber added to the test was plant specific considering that larger pieces of fiber are more likely to be trapped by the debris interceptors.

RESPONSE
The debris interceptor efficiency of 88% was utilized to decrease debris quantities. Also see the response to RAI 15d.

RAI 15f
Please include: Particulate debris size distributions.

RESPONSE
The particulate debris used during PTN4 strainer testing was prepared by PCI in accordance with a PCI Technical Document. As indicated in the response to RAI 11f, which asked for the characteristic size and size distribution of all debris used for the testing of the interceptors, the debris size category percentages for the NUKON® insulation is 8% fines, 25% small pieces, 32% large pieces and 35% remaining intact. This is consistent with NEI 04-07 guidance. A 10% erosion factor was included for small and large piece into fines. The foreign material fibrous quantity was assumed to be 100% fines.

RAI 15g
Please include: Test flow rates in gallons per minute.

RESPONSE
The maximum design flow through the Emergency Core Cooling System (ECCS) and the Containment Spray System (CSS) is 3,750 gpm. Based on the scaling factor of 6.8564% used during the Design Basis Test, the flow rate used during testing was ~257.2 gpm.

RAI 15h
Please include: A description of debris introduction including debris mixes and concentrations showing that non-prototypical agglomeration did not occur.

RESPONSE
The non-chemical debris was pre-wetted with heated water to help remove any entrained air. The fine fibrous debris is diluted with hot water (~120 °F) to approximate 3 parts water and 1 part fibrous debris (by volume). The diluted fine fiber is mixed with a paddle mixer attached to an electric drill to prevent agglomeration of the fine fiber. The particulate debris is also pre-wetted and mixed using a paddle mixer attached to an electric drill. The particulate and fibrous debris is also rinsed out of the holding containers during debris introductions to prevent the debris from agglomerating while entering the test flume. See Figures 15-3 and 15-4 below.

Figure 15-3 shows the fine fibrous debris diluted 3 parts water to 1 part pre-wetted fiber and being mixed with the paddle mixer. Figure 15-4 provides an example of the particulate debris being rinsed out into the test flume.

Figure 15-3: Fine Fiber Dilution and Mixing

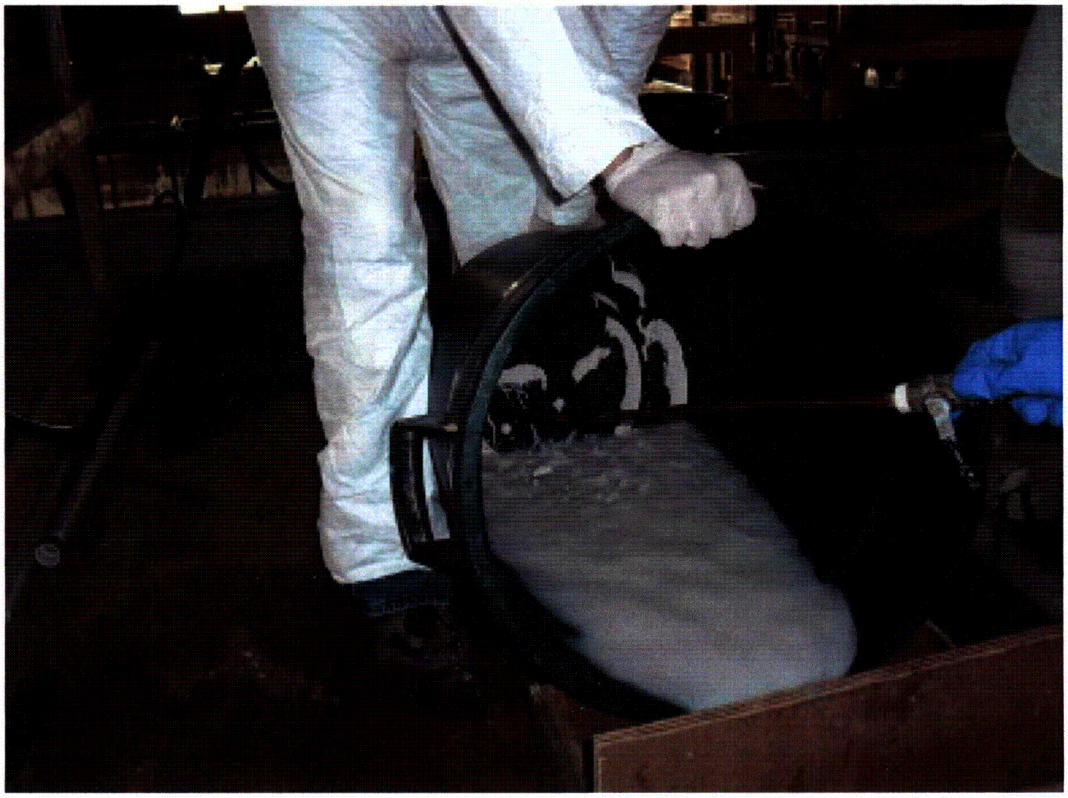


Figure 15-4: Particulate Debris being Rinsed into the Test Flume

RAI 15i
Please include: A flow velocity profile in feet per second in the flume as compared to plant flow velocities in the areas adjacent to the strainer.

RESPONSE
The velocity profile adjacent to the strainer assemblies for three strainer assemblies predicted by CFD compared to the velocity profile present during testing is presented in Figure 15-5. The velocity profile presented in the test flume is conservatively bounded and acceptable for testing.

**CFD Predicted Velocities**

| Distance from Point A (ft) | Target Velocity WT AVE (2X Max) (ft/s) 3 Strainer |
|---:|---:|
| 1 | 0.1246 |
| 2 | 0.1252 |
| 3 | 0.1359 |
| 4 | 0.1374 |
| 5 | 0.1486 |
| 6 | 0.1731 |
| 7 | 0.1606 |
| 8 | 0.1745 |
| 9 | 0.1764 |
| 10 | 0.1831 |
| 11 | 0.1780 |
| 12 | 0.1693 |
| 13 | 0.1688 |
| 14 | 0.1754 |
| 15 | 0.1768 |
| 16 | 0.1830 |
| 17 | 0.1863 |
| 18 | 0.1903 |
| 19 | 0.1857 |
| 20 | 0.1766 |
| 21 | 0.1729 |
| 22 | 0.1723 |
| 23 | 0.1633 |
| 24 | 0.1728 |
| 25 | 0.1803 |
| 26 | 0.1939 |
| 27 | 0.1973 |
| 28 | 0.1895 |
| 29 | 0.1864 |
| 30 | 0.1816 |

**Flume Velocities**

| Distance from Point A (ft) | Existing Flume Width (in) | Flume Velocity with 3 Strainer Flow Rate (ft) |
|---:|---:|---:|
| 1 | 16.4375 | 0.138246403 |
| 4 | 13.3125 | 0.17069861 |
| 8 | 11.4375 | 0.198681989 |
| 14 | 10.5 | 0.216421452 |
| 18 | 10.25 | 0.221700024 |
| 21 | 11.125 | 0.204262944 |
| 27 | 10.0625 | 0.225831081 |
| 30 | 11 | 0.206584114 |

Figure 15-5: Velocity Profiles of PTN4 Containment Compared to Velocity in Test Flume

## <u>RAI 16</u>

Please provide a graph of head loss versus time for the duration of the chemical effects testing, including the initial nonchemical portions. Include information regarding events that would be expected to affect the head loss such as debris addition, large flow changes, flow sweeps, etc.

## <u>RESPONSE</u>

Figure 16-1 below displays a plot of the measured head loss (ft) versus time (hours) for the PTN4 Design Basis Test.

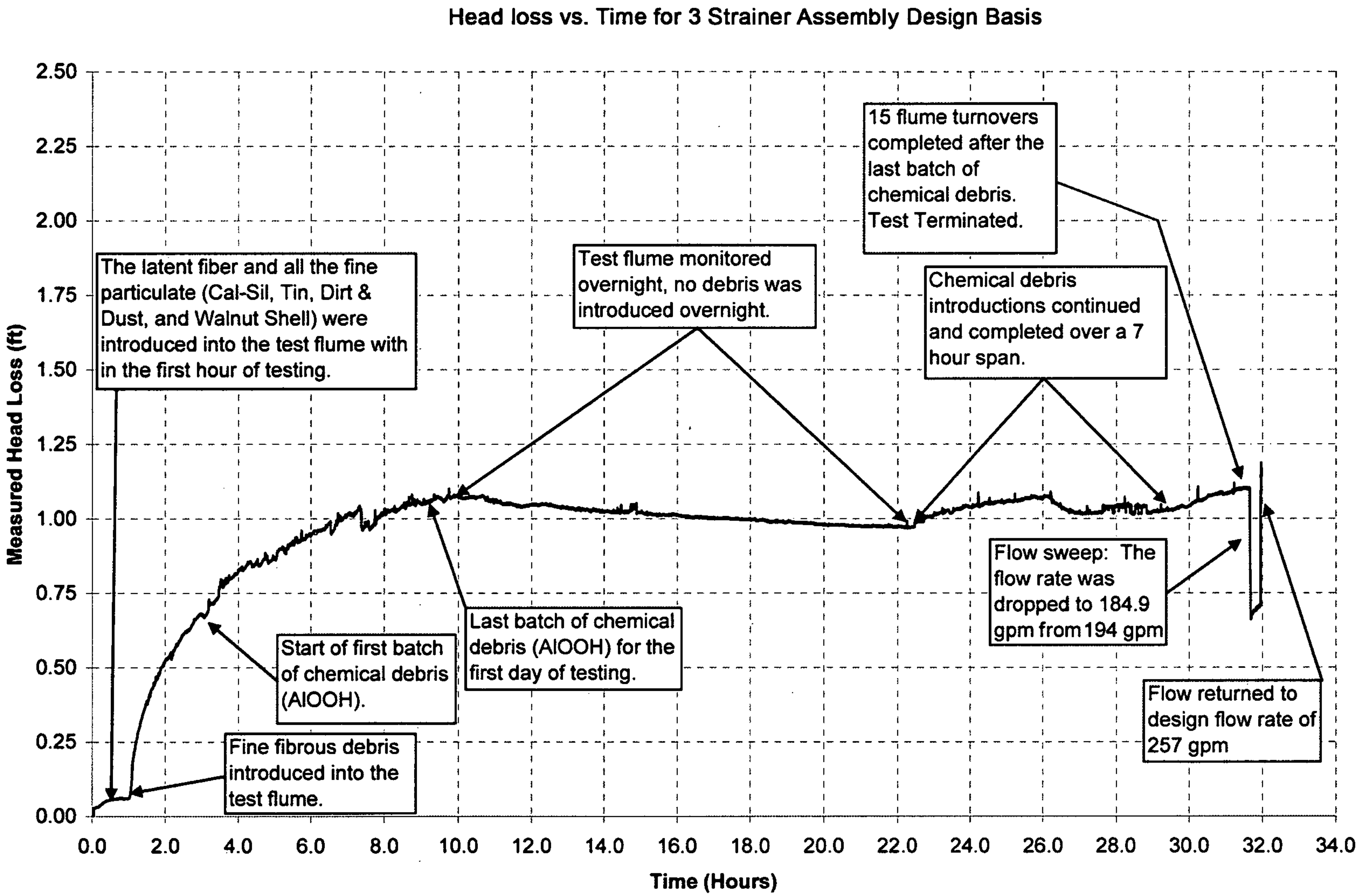


Figure 16-1 Plot of Measured Head Loss versus Time for Design Basis Test.

## RAI 17

Please provide the amount of debris that settled in the test flume during each test.

## RESPONSE

Three general tests were performed for PTN4 in which particulate, fiber, and chemical debris were introduced into the test flume. These tests consisted of a Design Basis Test, Fiber Bypass Test, and a Particulate Bypass Test. Tests were performed with no debris (Clean Strainer Test), tests were performed with miscellaneous debris (i.e. tags, labels, RMI – Debris Transport Test), and tests were performed with particulate, fiber, and chemical debris for PTN4. During testing, no official measurements were made with regards to the amount of debris that settled in the test flume. Following test termination, the test flume was drained and observations were made and documented.

Fiber Bypass Test – The fiber bypass test consisted of the design basis quantity of fibrous debris only. The amount of debris which settled on the test flume floor was not quantified following test flume drain down. There were no pictures or notes taken regarding the debris that settled within the test flume following the test.

Particulate Bypass Test – The particulate bypass test consisted of the design basis quantity of particulate debris only. The amount of debris which settled on the test flume floor was not quantified following test flume drain down. There were no pictures taken of the debris that settled within the test flume following the test.

Design Basis Test – The design basis test consisted of the design basis quantity of particulate, fiber, and chemical debris. The amount of debris which settled on the test flume floor was not quantified following test flume drain down. Visual observations were made of the test flume and documented by pictures following the design basis test. The following Figures 17-1 and 17-2 show the debris that had settled on the test flume floor following the Design Basis Test.

Figure 17-1  Debris Settled On Test Flume Floor During Drain Down

Figure 17-2  Zoomed View Of Debris Settled On Test Flume Floor During Drain Down

RAI 18

The supplemental response stated that the head loss determined by testing was extrapolated to higher temperatures expected during recirculation. The supplemental response indicated that a fiber-only test resulted in significant clean strainer area. It was not stated whether there were clean strainer areas following testing with chemicals and particulates. Clean strainer can result in turbulent flow which complicates attempts to viscosity correct head loss results to higher temperatures. It was not stated whether bore holes or other pressure driven phenomena occurred during testing. Flow sweeps should have been conducted to assure that a temperature extrapolation of head loss test data was valid. State the assumptions and their bases for the temperature extrapolation evaluation. Please state whether there was clean strainer area following the limiting chemical effects test. State whether there were bore holes or similar phenomena that occurred during testing.

RESPONSE

The strainer Test required a reduction in flow rate once the 15 flume turnovers was complete for the Design Basis Test. Thus, a flow sweep was performed at the end of the PTN4 Design Basis Test. During the flow sweep, the flow rate was dropped from 262.7 gpm to 189.4 gpm, thus causing the measured head loss to drop from 1.101 ft of water to 0.704 ft of water. This resulting measured head loss drop predicted that bore holes did not exist.

After drain down, the strainer had a bed of chemical debris covering the entire surface of the strainer, and there appeared to be no evidence of open strainer surface area. Thus, there were no clean strainer areas on the test strainer module, which can be seen in the pictures taken during test flume drain down. Figure 18-1 provides a picture at the start of test flume drain down with debris settled on top of the strainer module. Figure18-2 shows a zoomed view of the top and front edge of the strainer module during drain down.

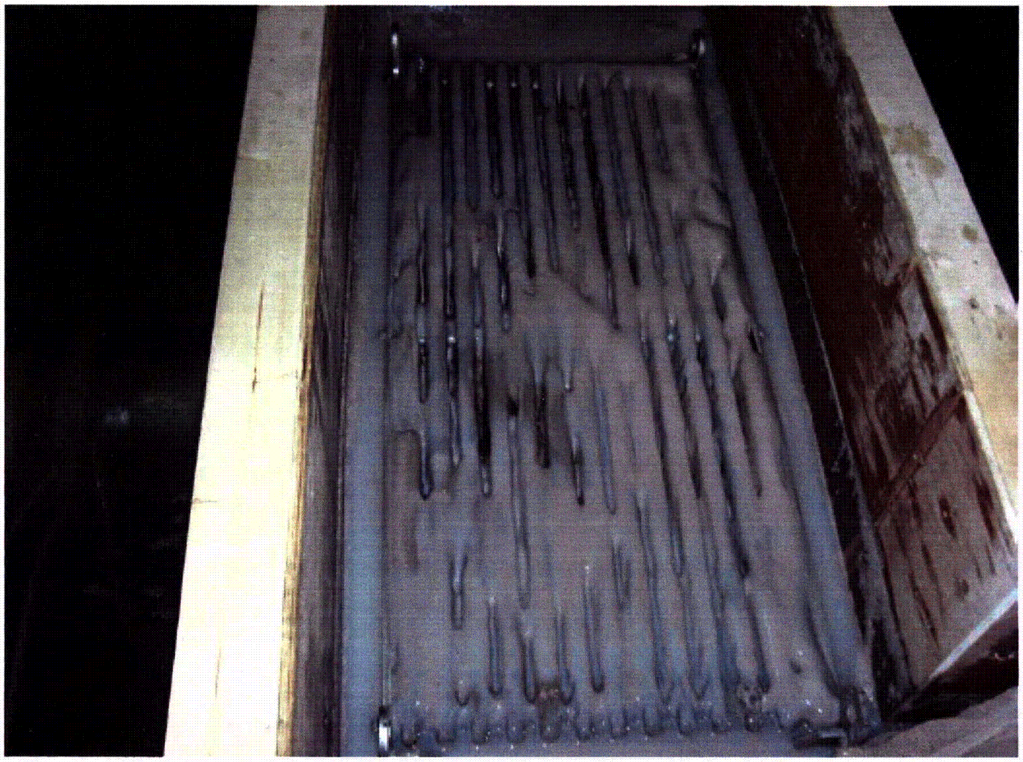


Figure 18-1 Top of the Test Strainer at the Start of Test Flume Drain Down

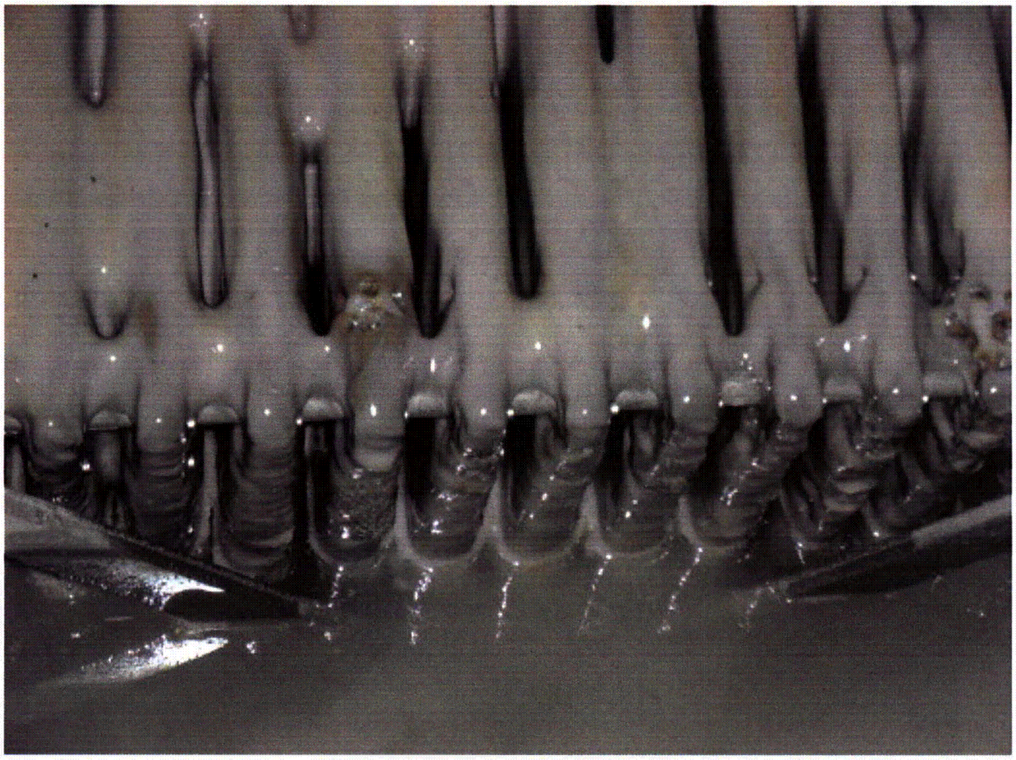


Figure 18-2 Zoomed Picture of the Test Strainer during Drain Down

RAI 19

Please provide the test data used to determine the extrapolation of head loss to the final mission time. Please provide the data set which was used to perform this extrapolation. Provide any assumptions used in this evaluation and their bases. Please note that the most recent staff guidance recognizes linear extrapolation as a conservative extrapolation method [Enclosure 1 of NRC letter to Nuclear Energy Institute. See Agencywide Documents Access and Management System Accession No. ML080230234].

RESPONSE

The following details the assumptions and describes the methodology used to extrapolate the head loss to the final mission time:

For a given strainer at a constant flow and given concentrations of a mix of fiber and particulate debris (both mass ratio and density ratio) reaching the strainer, the average amount of debris on the strainer and the consequent strainer head loss, both should rapidly increase with time as the debris accumulates rapidly on the strainer. Defining T0 as the turn over or flushing time equal to the total recirculation volume of water divided by the strainer flow, the number of elapsed flushing cycles (n) at any time t would be given by n = t / T0, where t is the time from initiation of recirculation flow. After several flushing cycles, the amount of debris reaching the strainer as well as the consequent head loss increase would be progressively reduced as the concentrations of debris gets lower and lower as they get filtered by the strainer and the accumulated debris cake on it. As long as a constant flow withdrawal through the strainer can be maintained, for all practical purposes, the amount of debris on the strainer and the strainer head loss, both would approach a constant value after several flushing cycles. The number of flushing cycles needed would depend on the debris types and concentrations and the strainer geometry.

An average debris thickness (L) on the strainer can be defined as the volume of debris on the strainer at any time divided by the strainer area. Theoretically, at the start of recirculation (t=0), the average debris thickness L=0, and as the number of flushing cycles (t / T0) approach infinity, L approaches a constant value. An exponential function would satisfy this requirement and hence, L can be expressed as,

$$L = C\,[1 - e^{-kt/T0}] \qquad (1)$$

In the above equation, C and k are constants for a given strainer with a constant flow and a constant mix of debris (fiber and particulates; mass ratios) entrained in the flow reaching the strainer.

The head loss due to strainer blockage at any instant of time is proportional to the average thickness of the debris bed on the strainer at that instant. Hence, based on Equation (1), the variation of ΔH with time (t) from initiation of the recirculation flow can be approximated by an equation of the form,

$$\Delta H = C1 + C2\,[1 - e^{-C3t/T0}] \qquad (2)$$

where, C1, C2 and C3 are constants to be evaluated by curve fitting of experimental data using the method of least squares or some other curve fitting method. It can be noted that at t=0, Equation (2) gives the clean strainer head loss (equal to C1) and as t approaches infinity, ΔH approaches a constant value (C1 + C2). Equation (2) may be used to extrapolate the value of head loss ΔH at any time t above the test duration, once the values of C1 and C2 are established based on the test data as shown in the table below.

No general assumptions were made in this evaluation. Raw data for the configurations are provided below.

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 0 | 1.038 | 1.0302 |
| 10 | 1.039 | 1.0304 |
| 21 | 1.04 | 1.0306 |
| 32 | 1.038 | 1.0308 |
| 42 | 1.037 | 1.0309 |
| 53 | 1.037 | 1.0311 |
| 63 | 1.037 | 1.0312 |
| 74 | 1.034 | 1.0314 |
| 84 | 1.032 | 1.0316 |
| 95 | 1.033 | 1.0318 |
| 105 | 1.035 | 1.0319 |
| 116 | 1.034 | 1.0321 |
| 127 | 1.036 | 1.0323 |
| 137 | 1.033 | 1.0324 |
| 148 | 1.037 | 1.0326 |
| 158 | 1.037 | 1.0327 |
| 169 | 1.034 | 1.0329 |
| 179 | 1.035 | 1.0331 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 190 | 1.038 | 1.0332 |
| 201 | 1.037 | 1.0334 |
| 211 | 1.034 | 1.0336 |
| 222 | 1.037 | 1.0337 |
| 232 | 1.039 | 1.0339 |
| 243 | 1.04 | 1.0341 |
| 253 | 1.039 | 1.0342 |
| 264 | 1.036 | 1.0344 |
| 274 | 1.038 | 1.0345 |
| 285 | 1.037 | 1.0347 |
| 296 | 1.04 | 1.0349 |
| 306 | 1.04 | 1.035 |
| 317 | 1.041 | 1.0352 |
| 327 | 1.039 | 1.0354 |
| 338 | 1.043 | 1.0355 |
| 348 | 1.041 | 1.0357 |
| 359 | 1.039 | 1.0358 |
| 370 | 1.039 | 1.036 |
| 380 | 1.043 | 1.0362 |
| 391 | 1.038 | 1.0363 |
| 401 | 1.041 | 1.0365 |
| 412 | 1.041 | 1.0367 |
| 422 | 1.039 | 1.0368 |
| 433 | 1.04 | 1.037 |
| 444 | 1.04 | 1.0371 |
| 454 | 1.039 | 1.0373 |
| 465 | 1.039 | 1.0374 |
| 475 | 1.045 | 1.0376 |
| 486 | 1.043 | 1.0378 |
| 496 | 1.042 | 1.0379 |
| 507 | 1.041 | 1.0381 |
| 518 | 1.04 | 1.0382 |
| 528 | 1.042 | 1.0384 |
| 539 | 1.042 | 1.0386 |
| 549 | 1.039 | 1.0387 |
| 560 | 1.043 | 1.0389 |
| 570 | 1.041 | 1.039 |
| 581 | 1.042 | 1.0392 |
| 591 | 1.043 | 1.0393 |
| 602 | 1.04 | 1.0395 |
| 613 | 1.04 | 1.0396 |
| 623 | 1.039 | 1.0398 |
| 634 | 1.041 | 1.04 |
| 644 | 1.041 | 1.0401 |
| 655 | 1.041 | 1.0403 |
| 665 | 1.041 | 1.0404 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 676 | 1.041 | 1.0406 |
| 687 | 1.039 | 1.0407 |
| 697 | 1.041 | 1.0409 |
| 708 | 1.042 | 1.041 |
| 718 | 1.04 | 1.0412 |
| 729 | 1.039 | 1.0413 |
| 739 | 1.038 | 1.0415 |
| 750 | 1.038 | 1.0416 |
| 760 | 1.038 | 1.0418 |
| 771 | 1.038 | 1.0419 |
| 782 | 1.036 | 1.0421 |
| 792 | 1.036 | 1.0423 |
| 803 | 1.036 | 1.0424 |
| 813 | 1.036 | 1.0426 |
| 824 | 1.037 | 1.0427 |
| 834 | 1.038 | 1.0429 |
| 845 | 1.037 | 1.043 |
| 856 | 1.036 | 1.0432 |
| 866 | 1.035 | 1.0433 |
| 877 | 1.037 | 1.0435 |
| 887 | 1.037 | 1.0436 |
| 898 | 1.035 | 1.0438 |
| 908 | 1.038 | 1.0439 |
| 919 | 1.037 | 1.0441 |
| 929 | 1.037 | 1.0442 |
| 940 | 1.036 | 1.0444 |
| 951 | 1.036 | 1.0445 |
| 961 | 1.037 | 1.0446 |
| 972 | 1.04 | 1.0448 |
| 982 | 1.039 | 1.0449 |
| 993 | 1.038 | 1.0451 |
| 1003 | 1.036 | 1.0452 |
| 1014 | 1.038 | 1.0454 |
| 1025 | 1.04 | 1.0455 |
| 1035 | 1.038 | 1.0457 |
| 1046 | 1.041 | 1.0458 |
| 1056 | 1.04 | 1.046 |
| 1067 | 1.04 | 1.0461 |
| 1077 | 1.039 | 1.0463 |
| 1088 | 1.042 | 1.0464 |
| 1099 | 1.038 | 1.0466 |
| 1109 | 1.039 | 1.0467 |
| 1120 | 1.042 | 1.0469 |
| 1130 | 1.041 | 1.047 |
| 1141 | 1.039 | 1.0471 |
| 1151 | 1.042 | 1.0473 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 1162 | 1.042 | 1.0474 |
| 1173 | 1.042 | 1.0476 |
| 1183 | 1.04 | 1.0477 |
| 1194 | 1.041 | 1.0479 |
| 1204 | 1.042 | 1.048 |
| 1215 | 1.044 | 1.0482 |
| 1225 | 1.044 | 1.0483 |
| 1236 | 1.044 | 1.0484 |
| 1247 | 1.043 | 1.0486 |
| 1257 | 1.043 | 1.0487 |
| 1268 | 1.043 | 1.0489 |
| 1278 | 1.043 | 1.049 |
| 1289 | 1.045 | 1.0492 |
| 1299 | 1.044 | 1.0493 |
| 1310 | 1.042 | 1.0494 |
| 1320 | 1.041 | 1.0496 |
| 1331 | 1.045 | 1.0497 |
| 1342 | 1.042 | 1.0499 |
| 1352 | 1.045 | 1.05 |
| 1363 | 1.045 | 1.0501 |
| 1373 | 1.047 | 1.0503 |
| 1384 | 1.046 | 1.0504 |
| 1394 | 1.045 | 1.0506 |
| 1405 | 1.047 | 1.0507 |
| 1415 | 1.049 | 1.0508 |
| 1426 | 1.046 | 1.051 |
| 1436 | 1.047 | 1.0511 |
| 1447 | 1.049 | 1.0512 |
| 1458 | 1.052 | 1.0514 |
| 1468 | 1.049 | 1.0515 |
| 1479 | 1.053 | 1.0517 |
| 1489 | 1.05 | 1.0518 |
| 1500 | 1.048 | 1.0519 |
| 1510 | 1.052 | 1.0521 |
| 1521 | 1.052 | 1.0522 |
| 1531 | 1.049 | 1.0523 |
| 1542 | 1.053 | 1.0525 |
| 1553 | 1.051 | 1.0526 |
| 1563 | 1.049 | 1.0528 |
| 1574 | 1.052 | 1.0529 |
| 1584 | 1.052 | 1.053 |
| 1595 | 1.053 | 1.0532 |
| 1605 | 1.051 | 1.0533 |
| 1616 | 1.05 | 1.0534 |
| 1627 | 1.051 | 1.0536 |
| 1637 | 1.051 | 1.0537 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 1648 | 1.054 | 1.0539 |
| 1658 | 1.055 | 1.054 |
| 1669 | 1.054 | 1.0541 |
| 1679 | 1.053 | 1.0542 |
| 1690 | 1.052 | 1.0544 |
| 1700 | 1.053 | 1.0545 |
| 1711 | 1.056 | 1.0547 |
| 1722 | 1.054 | 1.0548 |
| 1732 | 1.056 | 1.0549 |
| 1743 | 1.053 | 1.0551 |
| 1753 | 1.056 | 1.0552 |
| 1764 | 1.059 | 1.0553 |
| 1774 | 1.056 | 1.0555 |
| 1785 | 1.055 | 1.0556 |
| 1795 | 1.057 | 1.0557 |
| 1806 | 1.056 | 1.0559 |
| 1817 | 1.057 | 1.056 |
| 1827 | 1.056 | 1.0561 |
| 1838 | 1.054 | 1.0563 |
| 1848 | 1.057 | 1.0564 |
| 1859 | 1.054 | 1.0565 |
| 1869 | 1.056 | 1.0566 |
| 1880 | 1.06 | 1.0568 |
| 1890 | 1.06 | 1.0569 |
| 1901 | 1.059 | 1.057 |
| 1912 | 1.06 | 1.0572 |
| 1922 | 1.057 | 1.0573 |
| 1933 | 1.058 | 1.0574 |
| 1943 | 1.06 | 1.0576 |
| 1954 | 1.062 | 1.0577 |
| 1964 | 1.059 | 1.0578 |
| 1975 | 1.061 | 1.0579 |
| 1986 | 1.061 | 1.0581 |
| 1996 | 1.058 | 1.0582 |
| 2007 | 1.06 | 1.0583 |
| 2017 | 1.06 | 1.0585 |
| 2028 | 1.087 | 1.0586 |
| 2038 | 1.105 | 1.0587 |
| 2049 | 1.107 | 1.0588 |
| 2059 | 1.094 | 1.059 |
| 2070 | 1.06 | 1.0591 |
| 2080 | 1.058 | 1.0592 |
| 2091 | 1.059 | 1.0593 |
| 2102 | 1.059 | 1.0595 |
| 2112 | 1.06 | 1.0596 |
| 2123 | 1.061 | 1.0597 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 2133 | 1.064 | 1.0599 |
| 2144 | 1.062 | 1.06 |
| 2154 | 1.059 | 1.0601 |
| 2165 | 1.061 | 1.0602 |
| 2175 | 1.059 | 1.0604 |
| 2186 | 1.062 | 1.0605 |
| 2197 | 1.06 | 1.0606 |
| 2207 | 1.06 | 1.0607 |
| 2218 | 1.057 | 1.0609 |
| 2228 | 1.059 | 1.061 |
| 2239 | 1.064 | 1.0611 |
| 2249 | 1.061 | 1.0612 |
| 2260 | 1.061 | 1.0614 |
| 2271 | 1.059 | 1.0615 |
| 2281 | 1.058 | 1.0616 |
| 2292 | 1.058 | 1.0617 |
| 2302 | 1.058 | 1.0619 |
| 2313 | 1.061 | 1.062 |
| 2323 | 1.059 | 1.0621 |
| 2334 | 1.061 | 1.0622 |
| 2345 | 1.058 | 1.0624 |
| 2355 | 1.062 | 1.0625 |
| 2366 | 1.06 | 1.0626 |
| 2376 | 1.061 | 1.0627 |
| 2387 | 1.059 | 1.0628 |
| 2397 | 1.061 | 1.063 |
| 2408 | 1.06 | 1.0631 |
| 2419 | 1.059 | 1.0632 |
| 2429 | 1.061 | 1.0633 |
| 2440 | 1.062 | 1.0635 |
| 2450 | 1.059 | 1.0636 |
| 2461 | 1.061 | 1.0637 |
| 2471 | 1.062 | 1.0638 |
| 2482 | 1.058 | 1.0639 |
| 2492 | 1.063 | 1.064 |
| 2503 | 1.064 | 1.0642 |
| 2514 | 1.061 | 1.0643 |
| 2524 | 1.061 | 1.0644 |
| 2535 | 1.061 | 1.0645 |
| 2545 | 1.061 | 1.0646 |
| 2556 | 1.062 | 1.0648 |
| 2566 | 1.066 | 1.0649 |
| 2577 | 1.065 | 1.065 |
| 2587 | 1.066 | 1.0651 |
| 2598 | 1.064 | 1.0652 |
| 2609 | 1.062 | 1.0654 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 2619 | 1.063 | 1.0655 |
| 2630 | 1.063 | 1.0656 |
| 2640 | 1.064 | 1.0657 |
| 2651 | 1.063 | 1.0658 |
| 2661 | 1.065 | 1.066 |
| 2672 | 1.066 | 1.0661 |
| 2682 | 1.065 | 1.0662 |
| 2693 | 1.067 | 1.0663 |
| 2704 | 1.064 | 1.0664 |
| 2714 | 1.065 | 1.0665 |
| 2725 | 1.067 | 1.0667 |
| 2735 | 1.065 | 1.0668 |
| 2746 | 1.068 | 1.0669 |
| 2756 | 1.064 | 1.067 |
| 2767 | 1.064 | 1.0671 |
| 2778 | 1.065 | 1.0672 |
| 2788 | 1.065 | 1.0674 |
| 2799 | 1.067 | 1.0675 |
| 2809 | 1.066 | 1.0676 |
| 2820 | 1.067 | 1.0677 |
| 2830 | 1.07 | 1.0678 |
| 2841 | 1.068 | 1.0679 |
| 2852 | 1.069 | 1.0681 |
| 2862 | 1.067 | 1.0682 |
| 2873 | 1.069 | 1.0683 |
| 2883 | 1.07 | 1.0684 |
| 2894 | 1.07 | 1.0685 |
| 2904 | 1.069 | 1.0686 |
| 2915 | 1.07 | 1.0687 |
| 2926 | 1.07 | 1.0689 |
| 2936 | 1.073 | 1.069 |
| 2947 | 1.072 | 1.0691 |
| 2957 | 1.072 | 1.0692 |
| 2968 | 1.075 | 1.0693 |
| 2978 | 1.073 | 1.0694 |
| 2989 | 1.072 | 1.0695 |
| 2999 | 1.074 | 1.0696 |
| 3010 | 1.072 | 1.0697 |
| 3021 | 1.074 | 1.0699 |
| 3031 | 1.072 | 1.07 |
| 3042 | 1.079 | 1.0701 |
| 3052 | 1.076 | 1.0702 |
| 3063 | 1.074 | 1.0703 |
| 3073 | 1.075 | 1.0704 |
| 3084 | 1.074 | 1.0705 |
| 3095 | 1.075 | 1.0706 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 3105 | 1.076 | 1.0708 |
| 3116 | 1.077 | 1.0709 |
| 3126 | 1.075 | 1.071 |
| 3137 | 1.075 | 1.0711 |
| 3147 | 1.075 | 1.0712 |
| 3158 | 1.074 | 1.0713 |
| 3169 | 1.075 | 1.0714 |
| 3179 | 1.075 | 1.0715 |
| 3190 | 1.08 | 1.0716 |
| 3200 | 1.076 | 1.0717 |
| 3211 | 1.078 | 1.0719 |
| 3221 | 1.078 | 1.072 |
| 3232 | 1.078 | 1.0721 |
| 3243 | 1.075 | 1.0722 |
| 3253 | 1.078 | 1.0723 |
| 3264 | 1.075 | 1.0724 |
| 3274 | 1.078 | 1.0725 |
| 3285 | 1.076 | 1.0726 |
| 3295 | 1.077 | 1.0727 |
| 3306 | 1.077 | 1.0728 |
| 3316 | 1.077 | 1.0729 |
| 3327 | 1.077 | 1.073 |
| 3338 | 1.078 | 1.0732 |
| 3348 | 1.079 | 1.0733 |
| 3359 | 1.078 | 1.0734 |
| 3369 | 1.075 | 1.0735 |
| 3380 | 1.08 | 1.0736 |
| 3390 | 1.075 | 1.0737 |
| 3401 | 1.079 | 1.0738 |
| 3412 | 1.078 | 1.0739 |
| 3422 | 1.078 | 1.074 |
| 3433 | 1.078 | 1.0741 |
| 3443 | 1.077 | 1.0742 |
| 3454 | 1.078 | 1.0743 |
| 3464 | 1.08 | 1.0744 |
| 3475 | 1.078 | 1.0745 |
| 3486 | 1.081 | 1.0746 |
| 3496 | 1.078 | 1.0747 |
| 3507 | 1.077 | 1.0749 |
| 3517 | 1.081 | 1.075 |
| 3528 | 1.077 | 1.0751 |
| 3538 | 1.079 | 1.0752 |
| 3549 | 1.078 | 1.0753 |
| 3560 | 1.079 | 1.0754 |
| 3570 | 1.077 | 1.0755 |
| 3581 | 1.081 | 1.0756 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 3591 | 1.077 | 1.0757 |
| 3602 | 1.079 | 1.0758 |
| 3612 | 1.08 | 1.0759 |
| 3623 | 1.079 | 1.076 |
| 3633 | 1.078 | 1.0761 |
| 3644 | 1.079 | 1.0762 |
| 3654 | 1.08 | 1.0763 |
| 3665 | 1.08 | 1.0764 |
| 3676 | 1.081 | 1.0765 |
| 3686 | 1.081 | 1.0766 |
| 3697 | 1.08 | 1.0767 |
| 3707 | 1.082 | 1.0768 |
| 3718 | 1.082 | 1.0769 |
| 3728 | 1.082 | 1.077 |
| 3739 | 1.082 | 1.0771 |
| 3750 | 1.081 | 1.0772 |
| 3760 | 1.085 | 1.0773 |
| 3771 | 1.082 | 1.0774 |
| 3781 | 1.081 | 1.0775 |
| 3792 | 1.083 | 1.0776 |
| 3802 | 1.083 | 1.0777 |
| 3813 | 1.082 | 1.0778 |
| 3824 | 1.082 | 1.0779 |
| 3834 | 1.08 | 1.078 |
| 3845 | 1.081 | 1.0781 |
| 3855 | 1.082 | 1.0782 |
| 3866 | 1.08 | 1.0783 |
| 3876 | 1.079 | 1.0784 |
| 3887 | 1.079 | 1.0785 |
| 3897 | 1.081 | 1.0786 |
| 3908 | 1.083 | 1.0787 |
| 3919 | 1.085 | 1.0788 |
| 3929 | 1.084 | 1.0789 |
| 3940 | 1.081 | 1.079 |
| 3950 | 1.079 | 1.0791 |
| 3961 | 1.082 | 1.0792 |
| 3972 | 1.083 | 1.0793 |
| 3982 | 1.083 | 1.0794 |
| 3993 | 1.079 | 1.0795 |
| 4003 | 1.08 | 1.0796 |
| 4014 | 1.085 | 1.0797 |
| 4024 | 1.084 | 1.0798 |
| 4035 | 1.083 | 1.0799 |
| 4045 | 1.087 | 1.08 |
| 4056 | 1.084 | 1.0801 |
| 4067 | 1.085 | 1.0802 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 4077 | 1.086 | 1.0803 |
| 4088 | 1.083 | 1.0804 |
| 4098 | 1.085 | 1.0805 |
| 4109 | 1.085 | 1.0806 |
| 4119 | 1.085 | 1.0807 |
| 4130 | 1.085 | 1.0808 |
| 4141 | 1.083 | 1.0809 |
| 4151 | 1.083 | 1.081 |
| 4162 | 1.085 | 1.0811 |
| 4172 | 1.083 | 1.0812 |
| 4183 | 1.085 | 1.0813 |
| 4193 | 1.084 | 1.0814 |
| 4204 | 1.09 | 1.0815 |
| 4214 | 1.086 | 1.0816 |
| 4225 | 1.086 | 1.0816 |
| 4235 | 1.082 | 1.0817 |
| 4246 | 1.085 | 1.0818 |
| 4257 | 1.087 | 1.0819 |
| 4267 | 1.086 | 1.082 |
| 4278 | 1.087 | 1.0821 |
| 4288 | 1.086 | 1.0822 |
| 4299 | 1.09 | 1.0823 |
| 4309 | 1.087 | 1.0824 |
| 4320 | 1.087 | 1.0825 |
| 4330 | 1.086 | 1.0826 |
| 4341 | 1.086 | 1.0827 |
| 4352 | 1.086 | 1.0828 |
| 4362 | 1.089 | 1.0829 |
| 4373 | 1.087 | 1.083 |
| 4383 | 1.087 | 1.0831 |
| 4394 | 1.087 | 1.0832 |
| 4404 | 1.086 | 1.0832 |
| 4415 | 1.086 | 1.0833 |
| 4426 | 1.085 | 1.0834 |
| 4436 | 1.09 | 1.0835 |
| 4447 | 1.089 | 1.0836 |
| 4457 | 1.089 | 1.0837 |
| 4468 | 1.085 | 1.0838 |
| 4478 | 1.086 | 1.0839 |
| 4489 | 1.082 | 1.084 |
| 4499 | 1.079 | 1.0841 |
| 4510 | 1.08 | 1.0842 |
| 4521 | 1.081 | 1.0843 |
| 4531 | 1.084 | 1.0843 |
| 4542 | 1.083 | 1.0844 |
| 4552 | 1.084 | 1.0845 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 4563 | 1.084 | 1.0846 |
| 4573 | 1.081 | 1.0847 |
| 4584 | 1.082 | 1.0848 |
| 4594 | 1.084 | 1.0849 |
| 4605 | 1.085 | 1.085 |
| 4616 | 1.082 | 1.0851 |
| 4626 | 1.084 | 1.0852 |
| 4637 | 1.083 | 1.0853 |
| 4647 | 1.083 | 1.0853 |
| 4658 | 1.084 | 1.0854 |
| 4668 | 1.083 | 1.0855 |
| 4679 | 1.08 | 1.0856 |
| 4690 | 1.084 | 1.0857 |
| 4700 | 1.081 | 1.0858 |
| 4711 | 1.083 | 1.0859 |
| 4721 | 1.084 | 1.086 |
| 4732 | 1.084 | 1.0861 |
| 4742 | 1.082 | 1.0861 |
| 4753 | 1.084 | 1.0862 |
| 4764 | 1.082 | 1.0863 |
| 4774 | 1.082 | 1.0864 |
| 4785 | 1.081 | 1.0865 |
| 4795 | 1.084 | 1.0866 |
| 4806 | 1.084 | 1.0867 |
| 4816 | 1.083 | 1.0868 |
| 4827 | 1.087 | 1.0869 |
| 4838 | 1.085 | 1.0869 |
| 4848 | 1.085 | 1.087 |
| 4859 | 1.083 | 1.0871 |
| 4869 | 1.081 | 1.0872 |
| 4880 | 1.082 | 1.0873 |
| 4890 | 1.083 | 1.0874 |
| 4901 | 1.083 | 1.0875 |
| 4912 | 1.084 | 1.0876 |
| 4922 | 1.082 | 1.0876 |
| 4933 | 1.087 | 1.0877 |
| 4943 | 1.086 | 1.0878 |
| 4954 | 1.084 | 1.0879 |
| 4964 | 1.085 | 1.088 |
| 4975 | 1.086 | 1.0881 |
| 4986 | 1.086 | 1.0882 |
| 4996 | 1.085 | 1.0882 |
| 5007 | 1.085 | 1.0883 |
| 5017 | 1.085 | 1.0884 |
| 5028 | 1.083 | 1.0885 |
| 5038 | 1.086 | 1.0886 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 5049 | 1.085 | 1.0887 |
| 5059 | 1.087 | 1.0888 |
| 5070 | 1.089 | 1.0888 |
| 5081 | 1.087 | 1.0889 |
| 5091 | 1.084 | 1.089 |
| 5102 | 1.085 | 1.0891 |
| 5112 | 1.086 | 1.0892 |
| 5123 | 1.087 | 1.0893 |
| 5133 | 1.087 | 1.0893 |
| 5144 | 1.084 | 1.0894 |
| 5154 | 1.09 | 1.0895 |
| 5165 | 1.089 | 1.0896 |
| 5176 | 1.088 | 1.0897 |
| 5186 | 1.088 | 1.0898 |
| 5197 | 1.089 | 1.0899 |
| 5207 | 1.091 | 1.0899 |
| 5218 | 1.088 | 1.09 |
| 5228 | 1.089 | 1.0901 |
| 5239 | 1.09 | 1.0902 |
| 5250 | 1.088 | 1.0903 |
| 5260 | 1.089 | 1.0903 |
| 5271 | 1.091 | 1.0904 |
| 5281 | 1.088 | 1.0905 |
| 5292 | 1.09 | 1.0906 |
| 5302 | 1.09 | 1.0907 |
| 5313 | 1.088 | 1.0908 |
| 5324 | 1.092 | 1.0908 |
| 5334 | 1.09 | 1.0909 |
| 5345 | 1.09 | 1.091 |
| 5355 | 1.092 | 1.0911 |
| 5366 | 1.09 | 1.0912 |
| 5376 | 1.091 | 1.0912 |
| 5387 | 1.091 | 1.0913 |
| 5398 | 1.093 | 1.0914 |
| 5408 | 1.092 | 1.0915 |
| 5419 | 1.095 | 1.0916 |
| 5429 | 1.096 | 1.0917 |
| 5440 | 1.097 | 1.0917 |
| 5450 | 1.093 | 1.0918 |
| 5461 | 1.092 | 1.0919 |
| 5472 | 1.09 | 1.092 |
| 5482 | 1.091 | 1.0921 |
| 5493 | 1.09 | 1.0921 |
| 5503 | 1.094 | 1.0922 |
| 5514 | 1.083 | 1.0923 |
| 5524 | 1.089 | 1.0924 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 5535 | 1.093 | 1.0925 |
| 5546 | 1.089 | 1.0925 |
| 5556 | 1.088 | 1.0926 |
| 5567 | 1.093 | 1.0927 |
| 5577 | 1.09 | 1.0928 |
| 5588 | 1.092 | 1.0929 |
| 5598 | 1.119 | 1.0929 |
| 5609 | 1.103 | 1.093 |
| 5620 | 1.101 | 1.0931 |
| 5630 | 1.09 | 1.0932 |
| 5641 | 1.092 | 1.0933 |
| 5651 | 1.092 | 1.0933 |
| 5662 | 1.092 | 1.0934 |
| 5672 | 1.093 | 1.0935 |
| 5683 | 1.09 | 1.0936 |
| 5693 | 1.093 | 1.0936 |
| 5704 | 1.091 | 1.0937 |
| 5714 | 1.094 | 1.0938 |
| 5725 | 1.093 | 1.0939 |
| 5736 | 1.094 | 1.094 |
| 5746 | 1.094 | 1.094 |
| 5757 | 1.093 | 1.0941 |
| 5767 | 1.094 | 1.0942 |
| 5778 | 1.097 | 1.0943 |
| 5789 | 1.094 | 1.0943 |
| 5799 | 1.096 | 1.0944 |
| 5810 | 1.096 | 1.0945 |
| 5820 | 1.096 | 1.0946 |
| 5831 | 1.099 | 1.0946 |
| 5841 | 1.099 | 1.0947 |
| 5852 | 1.101 | 1.0948 |
| 5862 | 1.099 | 1.0949 |
| 5873 | 1.099 | 1.095 |
| 5884 | 1.099 | 1.095 |
| 5894 | 1.099 | 1.0951 |
| 5905 | 1.098 | 1.0952 |
| 5915 | 1.097 | 1.0953 |
| 5926 | 1.098 | 1.0953 |
| 5936 | 1.097 | 1.0954 |
| 5947 | 1.098 | 1.0955 |
| 5958 | 1.098 | 1.0956 |
| 5968 | 1.099 | 1.0956 |
| 5979 | 1.097 | 1.0957 |
| 5989 | 1.097 | 1.0958 |
| 6000 | 1.096 | 1.0959 |
| 6010 | 1.097 | 1.0959 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 6021 | 1.098 | 1.096 |
| 6032 | 1.097 | 1.0961 |
| 6042 | 1.098 | 1.0962 |
| 6053 | 1.097 | 1.0962 |
| 6063 | 1.097 | 1.0963 |
| 6074 | 1.102 | 1.0964 |
| 6084 | 1.102 | 1.0965 |
| 6095 | 1.1 | 1.0965 |
| 6105 | 1.099 | 1.0966 |
| 6116 | 1.098 | 1.0967 |
| 6127 | 1.099 | 1.0968 |
| 6137 | 1.098 | 1.0968 |
| 6148 | 1.097 | 1.0969 |
| 6158 | 1.097 | 1.097 |
| 6169 | 1.096 | 1.097 |
| 6179 | 1.097 | 1.0971 |
| 6190 | 1.098 | 1.0972 |
| 6201 | 1.096 | 1.0973 |
| 6211 | 1.102 | 1.0973 |
| 6222 | 1.099 | 1.0974 |
| 6232 | 1.102 | 1.0975 |
| 6243 | 1.099 | 1.0976 |
| 6253 | 1.099 | 1.0976 |
| 6264 | 1.097 | 1.0977 |
| 6275 | 1.096 | 1.0978 |
| 6285 | 1.098 | 1.0978 |
| 6296 | 1.102 | 1.0979 |
| 6306 | 1.1 | 1.098 |
| 6317 | 1.097 | 1.0981 |
| 6327 | 1.098 | 1.0981 |
| 6338 | 1.1 | 1.0982 |
| 6349 | 1.096 | 1.0983 |
| 6359 | 1.097 | 1.0983 |
| 6370 | 1.099 | 1.0984 |
| 6380 | 1.099 | 1.0985 |
| 6391 | 1.099 | 1.0986 |
| 6401 | 1.098 | 1.0986 |
| 6412 | 1.1 | 1.0987 |
| 6423 | 1.1 | 1.0988 |
| 6433 | 1.101 | 1.0988 |
| 6444 | 1.1 | 1.0989 |
| 6454 | 1.1 | 1.099 |
| 6465 | 1.1 | 1.099 |
| 6475 | 1.101 | 1.0991 |
| 6486 | 1.101 | 1.0992 |
| 6497 | 1.102 | 1.0993 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 6507 | 1.104 | 1.0993 |
| 6518 | 1.103 | 1.0994 |
| 6528 | 1.099 | 1.0995 |
| 6539 | 1.102 | 1.0995 |
| 6549 | 1.1 | 1.0996 |
| 6560 | 1.102 | 1.0997 |
| 6571 | 1.1 | 1.0997 |
| 6581 | 1.099 | 1.0998 |
| 6592 | 1.104 | 1.0999 |
| 6602 | 1.104 | 1.1 |
| 6613 | 1.1 | 1.1 |
| 6623 | 1.102 | 1.1001 |
| 6634 | 1.1 | 1.1002 |
| 6645 | 1.104 | 1.1002 |
| 6655 | 1.102 | 1.1003 |
| 6666 | 1.102 | 1.1004 |
| 6676 | 1.101 | 1.1004 |
| 6687 | 1.1 | 1.1005 |
| 6697 | 1.101 | 1.1006 |
| 6708 | 1.1 | 1.1006 |
| 6718 | 1.101 | 1.1007 |
| 6729 | 1.101 | 1.1008 |
| 6740 | 1.102 | 1.1008 |
| 6750 | 1.102 | 1.1009 |
| 6761 | 1.103 | 1.101 |
| 6771 | 1.104 | 1.101 |
| 6782 | 1.102 | 1.1011 |
| 6792 | 1.101 | 1.1012 |
| 6803 | 1.102 | 1.1012 |
| 6814 | 1.104 | 1.1013 |
| 6824 | 1.101 | 1.1014 |
| 6835 | 1.099 | 1.1014 |
| 6845 | 1.099 | 1.1015 |
| 6856 | 1.1 | 1.1016 |
| 6866 | 1.098 | 1.1016 |
| 6877 | 1.103 | 1.1017 |
| 6887 | 1.102 | 1.1018 |
| 6898 | 1.103 | 1.1018 |
| 6908 | 1.1 | 1.1019 |
| 6919 | 1.103 | 1.102 |
| 6930 | 1.101 | 1.102 |
| 6940 | 1.1 | 1.1021 |
| 6951 | 1.103 | 1.1022 |
| 6961 | 1.1 | 1.1022 |
| 6972 | 1.1 | 1.1023 |
| 6983 | 1.1 | 1.1024 |

| Time (sec) | Head Loss (ft) | Exponential |
|---|---|---|
| 6993 | 1.1 | 1.1024 |
| 7004 | 1.1 | 1.1025 |
| 7014 | 1.103 | 1.1026 |
| 7025 | 1.1 | 1.1026 |
| 7035 | 1.101 | 1.1027 |
| 7046 | 1.099 | 1.1028 |
| 7057 | 1.103 | 1.1028 |
| 7067 | 1.1 | 1.1029 |
| 7078 | 1.104 | 1.103 |
| 7088 | 1.101 | 1.103 |
| 7099 | 1.103 | 1.1031 |
| 7109 | 1.103 | 1.1031 |
| 7120 | 1.103 | 1.1032 |

RAI 20

Please verify that the head loss cases presented at 170°F and 300°F are the limiting cases for NPSH margin, and that other temperatures do not result in more limiting conditions. Please include the debris head loss and CSHL in this evaluation.

RESPONSE

NPSH was calculated at 10°F increments over the entire temperature range for each flow. It was determined that the minimum NPSH margin at the higher temperature range of 170°F to 300°F would occur when the sump saturation pressure equaled the minimum partial pressure of air that existed in containment at the start of the accident. The minimum NPSH margin at a flow of 2697 gpm is 6.53 ft. and occurs at a temperature of 196.5°F. The minimum NPSH margin at a flow of 3750 gpm is 7.22 ft. and occurs at a temperature of 170°F.

The response to RAI 25 explains how the flows for determining NPSH were selected. With containment spray in operation, the containment spray pumps and the HHSI pump are operated in piggyback mode with the RHR pumps supplying the suction pressure to these pumps. The calculation of record determines that the maximum flow rate in this mode is 2697 gpm. The applicable emergency operating procedure states that containment spray is required when containment pressure is greater than or equal to 14 psig or containment temperature is greater than or equal to 122°F. The maximum flow rate occurs in alignments that do not use containment spray. For conservatism the maximum flow rate was assumed to occur at 170°F, the maximum sump temperature at the end of 24 hours, down to a minimum sump temperature of 65°F. Based on the requirement for containment spray and the conservative assumption for temperature, the maximum flow rate from 170°F to a maximum temperature of 300°F is 2697 gpm. By establishing the minimum NPSH margins for flows of 2697 gpm and 3750 gpm all potential operating configurations in the recirculation mode are bounded.

Based on the test data and the head loss calculation the head losses are as follows:

Table 20-1
Head Loss Data

| FLOW, GPM | TEMP. °F | CLEAN STRAINER HEAD LOSS (CSHL) | DEBRIS LADEN HEAD LOSS, FT. | TOTAL HEAD LOSS, FT. |
|---|---|---|---|---|
| 3750 | 170 | 1.76 | 0.58 | 2.340 |
| 2697 | 300 | 0.91 | 0.289 | 1.199 |

In the calculation for NPSH the debris laden head loss was adjusted according to the dynamic viscosity at temperatures from 65°F to 300°F.

RAI 21
The flashing evaluation stated that accident pressure was not credited. However, the supplemental response stated that containment pressure was assumed to be the minimum allowable partial pressure of air at the start of the accident adjusted for temperature, plus the vapor pressure equivalent to the temperature of the sump water. The flashing analysis was conducted over a temperature range between 65 and 300° F. No margin to flashing was provided. The methodology and assumptions for the evaluation were also not provided. Please provide an evaluation of flashing across the debris bed and screen. Please provide the head loss margin available to prevent flashing. Please provide the assumptions and bases for this evaluation.

RESPONSE
Table 21-1 below shows the pressure available to preclude the water from flashing because of the pressure drop across the screen face. The column titled Over Pressure is the partial air pressure converted to feet of water plus the pressure of the sump water above the highest point of the screen minus the pressure drop across the screen. This is the head loss margin to prevent flashing.

Table 21-1
Evaluation for Flashing at Containment Sump Strainers

| TEMP | $P_{AIR}$ | $P_{VAP}$ | VISCOSITY | DENSITY | $HL_{SCREEN}$ | $WTR_{HEIGHT}$ | CONVERSION | OVER PRESSURE |
|---|---|---|---|---|---|---|---|---|
| °F | psia | psia | $lb_f$-sec/ft$^2$ | lb/ft$^3$ | ft. of water | ft. of water | psi/ft. water | ft. of water |
| 65 | 9.65641 | 0.3057 | 2.21E-05 | 62.34 | 1.5989 | 0.28 | 0.432903 | 20.98729 |
| 70 | 9.748376 | 0.3632 | 2.05E-05 | 62.31 | 1.487293 | 0.28 | 0.432674 | 21.32326 |
| 80 | 9.932308 | 0.5073 | 1.80E-05 | 62.22 | 1.306973 | 0.28 | 0.432083 | 21.96005 |
| 90 | 10.11624 | 0.6988 | 1.60E-05 | 62.12 | 1.160707 | 0.28 | 0.431361 | 22.5712 |
| 100 | 10.30017 | 0.9503 | 1.42E-05 | 62.00 | 1.038274 | 0.28 | 0.430528 | 23.16625 |
| 110 | 10.4841 | 1.2763 | 1.28E-05 | 61.68 | 0.940962 | 0.28 | 0.429597 | 23.74353 |
| 120 | 10.66803 | 1.6945 | 1.17E-05 | 61.71 | 0.85552 | 0.28 | 0.428564 | 24.317 |
| 125 | 10.76 | 1.9444 | 1.12E-05 | 61.63 | 0.821448 | 0.28 | 0.427997 | 24.5989 |
| 130 | 10.85197 | 2.225 | 1.07E-05 | 61.55 | 0.785082 | 0.28 | 0.427431 | 24.88376 |
| 140 | 11.0359 | 2.892 | 9.81E-06 | 61.38 | 0.722497 | 0.28 | 0.424917 | 25.52941 |
| 150 | 11.21983 | 3.277 | 9.05E-06 | 61.19 | 0.668571 | 0.28 | 0.424917 | 26.0162 |
| 160 | 11.40376 | 4.745 | 8.38E-06 | 60.99 | 0.621044 | 0.28 | 0.423569 | 26.58196 |
| 170 | 11.58769 | 5.996 | 7.80E-06 | 60.79 | 0.58 | 0.28 | 0.422132 | 27.1504 |
| 170 | 11.58769 | 5.996 | 7.80E-06 | 60.79 | 0.555368 | 0.28 | 0.422132 | 27.17504 |

Table 21-1
Evaluation for Flashing at Containment Sump Strainers

| TEMP | $P_{AIR}$ | $P_{VAP}$ | VISCOSITY | DENSITY | $HL_{SCREEN}$ | $WTR_{HEIGHT}$ | CONVERSION | OVER PRESSURE |
|---|---|---|---|---|---|---|---|---|
| °F | psia | psia | $lb_f$-sec/ft$^2$ | lb/ft$^3$ | ft. of water | ft. of water | psi/ft. water | ft. of water |
| 180 | 11.77162 | 7.515 | 7.26E-06 | 60.57 | 0.51878 | 0.28 | 0.420618 | 27.74771 |
| 190 | 11.95556 | 9.343 | 6.84E-06 | 60.34 | 0.490455 | 0.28 | 0.419049 | 28.31978 |
| 200 | 12.13949 | 11.529 | 6.37E-06 | 60.11 | 0.458682 | 0.28 | 0.41741 | 28.90422 |
| 210 | 12.32342 | 14.125 | 6.12E-06 | 59.86 | 0.442267 | 0.28 | 0.415708 | 29.48212 |
| 220 | 12.50735 | 17.188 | 5.86E-06 | 59.61 | 0.425746 | 0.28 | 0.413979 | 30.06677 |
| 230 | 12.69128 | 20.78 | 5.61E-06 | 58.80 | 0.413017 | 0.28 | 0.412132 | 30.6612 |
| 240 | 12.87521 | 24.97 | 5.36E-06 | 59.08 | 0.392511 | 0.28 | 0.410285 | 31.26866 |
| 250 | 13.05915 | 29.82 | 5.11E-06 | 58.80 | 0.375771 | 0.28 | 0.408326 | 31.88635 |
| 260 | 13.24308 | 35.42 | 4.85E-06 | 58.52 | 0.358869 | 0.28 | 0.406368 | 32.51 |
| 270 | 13.42701 | 41.85 | 4.60E-06 | 58.22 | 0.341889 | 0.28 | 0.404309 | 33.14788 |
| 280 | 13.61094 | 49.18 | 4.35E-06 | 57.92 | 0.324734 | 0.28 | 0.40225 | 33.79228 |
| 290 | 13.79487 | 57.53 | 4.09E-06 | 57.62 | 0.307468 | 0.28 | 0.400108 | 34.45043 |
| 300 | 13.9788 | 66.98 | 3.84E-06 | 57.31 | 0.290015 | 0.28 | 0.397965 | 35.11567 |

As shown in the table above, the partial pressure of air in containment was credited to prevent flashing. The partial pressure of air was determined using the most conservative assumptions. In accordance with the Technical Specifications the minimum containment pressure relative to atmosphere at which the plant may be operated is -2 psig. It is conservative to assume that vapor pressure is at a maximum. In accordance with the Technical Specifications the maximum containment temperature at which the plant may be operated is 125°F. The vapor pressure at this temperature is 1.94 psia. The initial containment pressure was thus determined as: 14.7 psia – 2 psi – 1.94 psi = 10.76 psia. The partial pressure of air was then adjusted according to temperature over the entire range from 65° to 300°.

Assumptions

1. It is assumed that the water in the sump is at saturation. This is a conservative assumption. The temperatures of the water in the containment sump are consistently lower than the temperature of the containment atmosphere. The pressure of the containment atmosphere is created by the steam produced during the LOCA and the partial pressure of air in containment. The temperature of the water in the containment sump is produced by the hot water created by the LOCA and the water from the RWST pumped into containment during the injection phase. The water from the RWST is at a much lower temperature than the water created by the LOCA. Therefore, it is conservative to assume that the water in the sump and the steam in the containment atmosphere are at saturation.

2. Heating of the air in containment behaves as an ideal gas.

3. Post LOCA containment atmosphere water vapor and air are at approximately the same temperature.

4. Containment atmospheric pressure at plant elevation is 14.7 psia.

5. Relative humidity in containment is conservatively considered to be 100%.

6. Post LOCA containment pool temperature is conservatively assumed to be equal to containment atmosphere temperature.

7. The partial pressure of air in containment at the beginning of the postulated LOCA can be credited for the purposes of evaluating head loss margin to flashing at the ECCS/CS sump screen debris bed.

8. Debris bed head loss values for the large break LOCA are compared to the submergence for small break LOCA even though debris generated and transported for the SBLOCA is significantly less.

9. Flow rates through the ECCS/CS suction strainer debris bed are laminar with associated head losses varying with kinematic viscosity.

RAI 22
Please provide the assumptions and methods used to evaluate the maximum recirculation sump flow rates. Please specifically discuss the basis for the timing of 24 hours into the event for a change in sump flow from 2697 gallons per minute (gpm) to 3750 gpm, as well as the pump operating configurations, assumptions, and methodology to calculate the flows for both cases.

RESPONSE
The flow rates are dependent upon the flow alignments. The allowable flow alignments are dependent upon containment pressure and temperature. The applicable emergency operating procedure (EOP) states that containment spray is required when containment pressure is greater than 14 psig or containment temperature is greater than 122°F. When containment spray is required in the recirculation mode one RHR pump must take suction from the containment sump and discharge to one HHSI pump and one containment spray pump. The limiting NPSH case for the RHR pumps during the short term circulation alignments was determined to be the High-Head/Cold-Leg recirculation with containment spray alignment. The calculated flow rate for this configuration is 2697 gpm. The flow in piggyback operation is higher to the cold legs than to the hot legs.

The maximum flow rate occurs in alignments that do not use containment spray. This maximum flow rate is assumed to be 3750 gpm. This is a conservative assumption since the flow rate of each RHR pump is limited to this maximum by valve HCV-4-758 (RHR heat exchanger outlet common header discharge valve).

The use of 24 hours as the time period to differentiate the flow rates is based on a previous procedural requirement to only use one RHR pump in the first 24 hours post LOCA. The use of one RHR pump was to prevent flashing when the sump temperature was greater than or equal to 212°F. The use of two RHR pumps was allowed after 24 hours. After the installation of the containment sumps the EOPs were changed to allow the use of only one RHR pump for the entire time of the accident. It was determined during the design of the containment sump strainers that the number of strainers required to allow the flow rate for two RHR pumps was excessive. However, the specification for the strainers still used the 24 hour period to differentiate flows. Testing for the containment strainers was based on a temperature range from 65°F to 300°F and a maximum temperature of 170°F 24 hours after the accident. Therefore, the strainers had to meet the specified pressure drops with a flow of 3750 gpm at temperatures from 65°F to 170°F and a flow 2697 gpm at temperatures from 170°F to 300°F. The maximum flow of 3750 gpm actually cannot occur until containment spray is secured. Containment spray is required when the containment temperature is greater than or equal to 122°F and/or containment pressure is greater than or equal to 14 psig.

RAI 23

Please provide the method used for estimation of the suction side head losses in the suction lines. The hydraulics methodology, the source of pipe loss data, and the source of the loss coefficients should be discussed, as well as any codes used to calculate the results.

RESPONSE

To calculate the head losses in the clean piping, plenums, and the elbows, the following assumptions were made:

1. An increase of 10% for the connecting piping, plenum, and fittings head loss was used to address any non conservatism inherent in the use of standard head loss correlation equations.
2. The relative roughness coefficient is assumed to be 0.001 for the internal flow resulting in a friction coefficient of 0.013 for smooth flow for the piping, plenums, and fittings.

The Darcy-Weisbach equation, $HL = f \times (L/D) \times V^2/2g$, was used for the piping.

For the elbows, the pipe reducers, the tee fitting, the opening to the plenums, and the exit from the plenum, the equation was $HL = K \times V^2/2g$.

For the head loss through the plenum the equation was $HL = K \times L/R \times V^2/2g$.

The reference for the K values was Crane Technical Paper No. 410, Flow of Fluids through Valves, Fittings, and Pipe, 1988.

There were no codes used to calculate the results. The calculation was performed using EXCEL.

The maximum head loss to the north sump is bounding and is the head loss stated in the hydraulic report and used in subsequent calculations. The hydraulic report calculates the head loss through the strainers to where the piping penetrates the containment floor.

Pressure drop for the suction line from where it penetrates the containment floor to the pump suction was based on the existing calculations for NPSH. To determine the pressure drops from the existing calculation for different flows the relationship that pressure drop is proportional to the velocity squared was used.

RAI 24

The supplemental response stated that the net positive suction head required (NPSHr) values for the emergency core cooling system (ECCS) and CSS pumps were based on pump test curves. While use of NPSHr data provided by the manufacturer may be acceptable, it is not clear whether the equivalent of the 3 percent criterion of Regulatory Guide 1.82, Revision 3 was used. Please provide the basis for the NPSHr values for the ECCS and CSS pumps.

RESPONSE

The curve for NPSHr supplied by Ingersoll Rand for the RHR pumps is based on 3% pump head loss degradation. The RHR pumps provide the suction to the HHSI and containment spray pumps during recirculation. The NPSHr for the HHSI pump at runout is 30 ft. The NPSHr for the containment spray pump at runout is 35 ft. The RHR pump head at runout is 165 ft., which is well in excess of the NPSHr for these pumps. The suction pressure supplied to the HHSI and containment spray pumps during recirculation is sufficient to account for a 3% pump head loss degradation for the NPSH required for these pumps.

RAI 25

The supplemental response does not discuss the distinction between cold-leg and hot-leg recirculation scenarios, in which the pump lineups and, therefore, the flow rates, may vary. If plant procedures address both scenarios, please provide the NPSH results for both scenarios or provide arguments that one or the other scenario is bounding.

RESPONSE

The limiting NPSH case for the RHR pumps during the short term recirculation alignments was determined to be the High-Head/Cold-Leg recirculation with containment spray alignment. The alignment for this case is one RHR pump discharging to one HHSI pump and one containment spray pump in piggyback operation. The calculation of record for this configuration determines the flow rate is 2697 gpm. This calculation shows that the flow in piggyback operation is higher to the cold legs than to the hot legs.

The applicable emergency operating procedure states that containment spray is required when containment pressure is greater than or equal to 14 psig or containment temperature is greater than or equal to 122°F. The maximum flow rate occurs in alignments that do not use containment spray. This maximum flow rate is assumed to be 3750 gpm. This is a conservative assumption since the flow rate of each RHR pump is limited to this maximum by valve HCV-4-758.

Therefore, by establishing the minimum NPSH margins for flows of 2697 gpm and 3750 gpm all potential operating configurations in the recirculation mode are bounded. The minimum NPSH margin at a flow of 2697 gpm is 6.53 ft. and occurs at a temperature of 196.5°F. The minimum NPSH margin at a flow of 3750 gpm is 7.22 ft. and occurs at a temperature of 170°F. Note that this NPSH margin is determined at a temperature greater than 122°F; i.e., at a temperature when containment spray is required and the configuration for recirculation would limit RHR flow to a maximum of 2697 gpm. To ensure conservatism in the design of the sump strainers flows were specified based on time periods of up to and after 24 hours and the maximum temperatures that can occur. The maximum containment sump temperature at the end of 24 hours is 170°F. The NPSH calculation was based on these same flow rates.

RAI 26

Table 3.g-1 in the supplemental response dated August 11, 2008, lists the pressurizer relief tank as a source of water for the containment pool. This assumption appears to be the only difference between the water source assumptions betweens Units 3 and 4. However, the total volumes of water added to the containment pool are identical for both units. Please clarify the assumptions made for Unit 4 with respect to the pressurizer relief tank as a water source for the post-loss-of-coolant accident (LOCA) containment pool.

RESPONSE

The value of 10,852 $ft^3$ shown in Table 3.g-1, the sum of the sources of water in containment, is the correct value and does not include the 1300 $ft^3$ shown for the pressurizer relief tank. The 1300 $ft.^3$ of water shown in Table 3.g-1 for the pressurizer relief tank should have been 0.0 $ft.^3$ and was a clerical error. The other values shown in Table 3.g-1 are correct. The water source assumptions made for both Units 3 and 4 are the same and are applicable to both units at Turkey Point.

RAI 27

Please discuss any water holdup volumes in containment sumps, pits or cavities.

RESPONSE

The containment sump strainers are anchored to the floor at elevation 14 feet. The water below 14 feet is in a pit below the reactor vessel. The amount of water available to fill the containment sump is reduced by 9,278 cubic feet to account for this pit.

RAI 28

Please clarify whether the exchange of reactor coolant system water at operational temperature with cooler, denser, refueling water storage tank water was evaluated as a holdup mechanism.

RESPONSE

The exchange of RCS water at operational temperature with cooler, denser RWST water temperature was considered. The water in the RWST was assumed to be at a temperature of 100°F to minimize the amount of water that would be contributed. The sump temperature was considered to be a conservatively low temperature of 190°F. The volume of water in the containment sump was based on converting the density of water from all sources from its temperature prior to the accident to a temperature of 190°F. The net effect of the above did result in a hold up mechanism that was included in the calculation for minimum containment sump level.

RAI 29

For a LOCA caused by a leak at the top of the pressurizer, please clarify whether the filling of the steam space in the pressurizer was considered as a hold-up volume.

RESPONSE

The filling of the steam space in the pressurizer was considered as a hold up volume for the small break LOCA. For a small break LOCA the entire volume of the RCS was considered to fill water solid. It was not considered as a hold up volume for a large break LOCA. Such a leak could have been considered since the ECCS would fill the pressurizer if a large break LOCA would occur at the top of the pressurizer. However, the amount of debris generated and the pressure drop across the strainers would be decreased. The pressurizer has a water volume of 780 cubic feet and a steam volume of 520 cubic feet for a total volume of 1300 cubic feet. The water elevation determined by not accounting for the 1300 cubic feet to fill the pressurizer was 17.35 feet. If the 1300 cubic feet is subtracted from the volume of water in the containment sump the water elevation is 17.19 feet. This water elevation is greater than the elevation used to determine NPSH. To determine NPSH the elevation of the water for a small break LOCA, 17.03 feet, was used.

RAI 30

Please provide a basis for the assumption that the 6-inch diameter refueling canal drains cannot be blocked by debris. Large pieces of insulation or other debris can be this size or larger and some fraction of them could be blown into the upper containment and potentially reach the refueling canal drains. Please consider temporary floatation and transport over the drain due to refueling canal drain surface currents, absorption of water into the material, and subsequent sinking of the material to cover the drains.

RESPONSE

FPL has performed containment design reviews and walkdowns to assess flow chokepoints and flow paths from potential high energy break locations to the containment sump suction strainers including upwards from inside the biological shield wall through the floor at elevation 58' and into the refueling cavity and outside the biological shield wall. This review concluded that the refueling canal drains could become chokepoints with the perforated drain covers installed. The drain covers were removed in accordance with the modification that installed the strainers. The limiting breaks are within the secondary biological shield wall around the RCS loop level. The pathways from the loops up and through the 58' level floor are torturous. This is due to the large solid floor area above the secondary shield wall and the grating above the area outside the shield wall at elevation 58', relatively small compartment areas covered with grating, and tight clearances around stairs, curbs and penetrations.

The refueling pool is surrounding almost completely by a 4" high curb. The curb is either a 4" x 4" concrete curb or an 8" wide stainless steel curb depending on the location around the refueling canal. The only location where no curb exists is on the east side for a length of 2' – 6".

While there is no exact way to quantify the type, size and shape, if it is assumed that significant debris is able to make its way vertically over 40 feet against the forces of gravity through the aforementioned tortuous path, the following design features preclude total blockage of both drain paths:

- Any debris that lands on the 58' elevation and not directly in the refueling canal must be washed over a 4" high curb to fall into the refueling canal with the exception of a 2' – 6" opening in the curb on the east end.

- Drains are redundant.

- Drains are separated 6' – 6".

- Drain diameters are large, 6", so that larger debris of conforming size would be required to simultaneously block and perfectly seal both drains without pass through for significant water holdup.

- The drain covers are removed during normal operation to allow smaller debris to pass through the drain.

- The refueling cavity is large with a lot of area for debris to 'hide out'.

Therefore, the fuel transfer canal drains do not create a chokepoint at PTN4.

RAI 31

The NRC staff considers in-vessel downstream effects to not be fully addressed at Turkey Point Unit 4 as well as at other PWRs. Turkey Point Unit 4's supplemental response refers to draft WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final safety evaluation (SE) for WCAP-16793-NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for Turkey Point Unit 4 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 alternatively resolve this item by demonstrating, without reference to WCAP-16793 or the staff SE, that in-vessel downstream effects have been addressed at Turkey Point Unit 4. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793. The NRC staff is developing a Regulatory Issue Summary to inform the industry of the staff's expectations and plans regarding resolution of this remaining aspect of GSI-191.

RESPONSE

FPL was at the recent joint NEI/NRC meeting on January 14 and 15, 2009 regarding issues related to the final resolution of Generic Issue 2004-02. This RAI-31 and presentations by the NRC are understood and actions will be taken by FPL to meet the requested NRC schedule. FPL is confident that it will be able to demonstrate that Turkey Point Unit 4 in-vessel downstream effects will be bounded by the final version of WCAP-16793-NP. Also, at this time, FPL believes that Turkey Point Unit 4 will be in compliance with the NRC's safety evaluation of the final WCAP-16793-NP.

In FPL's August 11, 2008 supplemental response on Generic Letter 2004-02, the response to Topic 3.n stated that Turkey Point Unit 4 was bounded by the generic results for in-vessel fuel effects related to fiber and debris bypass contained in WCAP-16793-NP, Rev.0. As further noted in the response to Topic 3.n, Turkey Point Unit 4 performed a unit specific analysis for chemical plate out on the fuel that yielded satisfactory results for fuel temperatures of only 366 °F. In the August 11, 2008 supplemental response, Attachment 2, Enclosure 2, FPL also provided Turkey Point Unit 4 responses to NRC staff's Limits and Conditions related to the staff's initial review of WCAP 16793-NP.

FPL believes that sufficient evaluation has been conducted for Turkey Point Unit 4 to demonstrate acceptable in-vessel conditions. However, at the recent joint NEI/NRC meeting on January 14 and 15, 2009, NRC requested industry assurance that plants will submit a final in-vessel evaluation within 90 days after NRC issues a safety evaluation (SE) on the final version of WCAP-16793-NP. FPL will evaluate the NRC SE at the time of issuance to determine if there are additional impacts that require new or different methods for evaluating this issue. FPL fully intends to meet NRC's schedule request.

RAI 32

Your June 30, 2008, response to GL 2004-02 states that the final sump fluid pH is achieved by manual addition of sodium tetraborate (STB) following a LOCA rather than by dissolution of STB already stored in the lowest elevation of the reactor building. Please provide the procedure for addition of STB following a LOCA. Where is the STB stored during normal plant operation?

How is the STB transported to the containment building and how is it physically added to the sump?

RESPONSE

Post Loss of Coolant Accident (LOCA) sump recirculation water is buffered with sodium tetraborate decahydrate manually from outside the containment. Sodium tetraborate decahydrate, which is stored in the Central Receiving Warehouse, is moved to the boric acid batching tank area in the auxiliary building, which is outside of containment.

The post accident chemical injection process is entered from either the "Loss of Reactor or Secondary Coolant" procedure for very small breaks where more than 155,000 gallons remains in the refueling water storage tank (RWST), or from the "Transfer to Cold Leg Recirculation" procedure for a break size where less than 155,000 gallons remains in the RWST. Both procedures contain the same system alignments and processes for mixing and transferring the buffer solution from the boric acid batching tank to the charging portion of the chemical and volume control system.

Water from the primary water system is used to fill the boric acid batching tank to a level specified by procedure. Sodium tetraborate decahydrate is manually added to the tank and mixed until in solution. One of three boric acid transfer pumps is selected and valves are manipulated to transfer the buffer solution to one of three charging pumps. This injection alignment to the reactor coolant system continues until the boric acid storage tank contents are injected into the RCS. The buffered water spills out of the break and mixes with containment sump water inside of containment. The first batch of buffer solution is injected into the reactor coolant system within eight hours following a LOCA. As required, Nuclear Chemistry samples recirculation flow and determines sump pH in the hot lab. This process for batching and injecting buffer solution is repeated until the containment sump pH is greater than 7.2.

RAI 33

What surveillance requirements are in place to ensure that the required quantity of STB is available to provide adequate sump buffering? The warehouse is humidity controlled.

RESPONSE

Turkey Point Nuclear Plant procedure "Schedule for Plant Checks and Surveillances" requires quarterly verification to: "Ensure that 66 drums of Borax (Sodium Tetraborate Decahydrate) are available in the Central Receiving Warehouse."

RAI 34

What surveillance requirements are in place to ensure that the STB's chemical and physical properties are maintained in a manner that allows for timely addition, dissolution, and adequate pH control? Are chemical tests performed periodically to ensure the buffer capacity of the stored STB? Are physical tests performed to ensure that densification of the STB has not occurred over time? If the STB is exposed to humid conditions in the storage facility, the pellets/granules may solidify which would impede both dissolution and addition to the sump. How is this potential phenomenon addressed at Turkey Point?

RESPONSE

As discussed in the response to RAI-32, the emergency operating procedures call for the addition of the first batch of buffer within eight hours. This period of time is sufficient to prepare for and stage the sodium tetraborate decahydrate near the boric acid batching tank room in preparation for the first round of batching. The boric acid batching tank has an electric mixer which is sufficient to insure dissolution of the chemical into solution. In the event the in-place mixer is out of service, the emergency operating procedures direct the technical support center staff to set up a nitrogen bottle and sparging rod at the tank to facilitate mixing. Sodium tetraborate decahydrate is accepted by the NRC as a suitable chemical for pH control of post-LOCA sump water. Calculations for post-LOCA sump pH control with this buffer are in-place, and the emergency operating procedures for mixing and injecting the buffer solution comply with requirements. Per procedure, the pH is checked by Nuclear Chemistry and when sump pH gets to 7.2 further addition of buffer is not required.

As discussed in RAI-33, the storage and availability of the material is covered under a procedure that assures the availability on demand of sufficient quantity of the material. However, the material is not included in other plant chemical specification or verification procedures.

FPL conducted a visual inspection to ensure that the material was still granular in nature during preparation of this response. FPL will analyze a sample to ensure its suitability and will periodically re-sample. FPL will proceduralize this requirement.

RAI 35

Because addition of the STB is performed manually (as opposed to a passive system in the containment) the amount of time required to add the required amount to buffer the sump pool may be longer than for the passive addition case. Please provide the amount of time needed to manually add the required amount of STB. Has the dose for personnel associated with the manual addition process been estimated, and if so, what is that dose per person? Does the time dependant sump pH profile used to determine material dissolution (e.g. aluminum, calcium, silica) account for the time required to manually add the STB?

RESPONSE

As noted in the response to RAI-32, emergency operating procedures require the addition of sodium tetraborate decahydrate to begin within eight hours following a loss of coolant accident (LOCA). Calculations for the addition of the buffer, via emergency operating procedures, result in a sump pH starting at 4.95 and increasing to a pH of 7.2 within approximately 39 hours from the start of buffer addition. This is based on a one hour batch and addition cycle time by operations. Hence, the post-LOCA sump pH profile for Turkey Point Unit 4 is from 4.95 to 7.2 over a 48 hour period.

It is noted that RAI-32 questions post-LOCA operator actions inside or near containment with regards to the mixing and addition of buffer solution. As discussed in RAI-32, the mixing and transfer of buffer solution to the containment sump is conducted in the auxiliary building outside of containment and away from containment shine. Following the accident at Three Mile Island, a dose and shielding review was conducted for Turkey Point Units 3 and 4 in accordance with the recommendations and limits established by NUREG-0578 regarding TMI-2 short term lessons learned. These criteria endorsed 10 CFR 50, Appendix A, GDC-19 limits of 5 Rem for these types of post-LOCA operator actions and were also adopted by NUREG-0737 regarding TMI action plan requirements. The dose and shielding review included the boric acid batching room and resulted in recommendations for physical changes and additional analysis to meet these dose criteria. Subsequent NRC inspections and the issuance of the Safety Evaluation Report concluded that plant changes and analysis were in compliances with the criteria of GDC-19 for plant personnel radiation exposures.

This sump pH timing profile, discussed earlier, was used as input to the Turkey Point Unit 4 calculations using the LOCA Deposition Model (LOCADM) developed by the Westinghouse Owners Group and as input to post-LOCA chemical analysis and testing conducted by AREVA and Alden Research Laboratory.

RAI 36

The June 30, 2008, supplemental response states that buffer addition occurs until a pH of 7.2 is achieved. How is the sump fluid pH monitored following a LOCA to ensure that an adequate quantity of STB has been added to achieve a pH of no lower than 7.2?

RESPONSE

As discussed in the response to RAI-32, emergency operating procedures require post-LOCA buffer addition to begin within eight hours, and continue until Nuclear Chemistry determines via sampling that sump recirculation flow pH is determined to be over 7.2. Current emergency operating procedures do not call out longer term monitoring of sump pH beyond the determinations discussed earlier. Operations support will continue via the Technical Support Center (TSC), and operations will also be provided with long term post accident monitoring assistance from the Emergency Operations Facility (EOF). This assistance assures continued monitoring of all long-term post accident parameters.

RAI 37

Please clarify your intention to update the Turkey Point Unit 4 Final Safety Analysis Report, in accordance with Title 10, *Code of Federal Regulations*, Section 50.71(e), to include a description of the new sump strainer, its design basis, and the analyses performed that were associated with the post accident debris evaluation.

RESPONSE

The combined Turkey Point Unit 3/4 Updated Final Safety Analysis Report (UFSAR) currently contains descriptions of the new sump strainers (see pages 6.2-9 and 6.2-10; Figures 6.2-12 and -13; and page 6.4-9). The UFSAR was updated November 11, 2008 to include this information.

The UFSAR will be also updated to include references to the Unit 3 and Unit 4 plant change /modification (PC/M) documents that implemented the changes to address the NRC Generic Safety Issue 191, “Assessment of Debris Accumulation on PWR Sump Performance”.

These PC/Ms contain or refer to the detailed, extensive descriptions of the new sump strainers, their design bases, and the analyses performed that were associated with the post accident debris evaluations. This satisfies the requirements of 10 CFR 50.71(e).

RAI 38

The supplemental responses for Turkey Point Unit 3 stated that the original sump design and replacement strainer design did not include trash racks. However, the staff noted that existing TS 4.5.2.e.3, which is identical for Units 3 and 4, refers to trash racks being present. Based upon the supplemental responses for Turkey Point Unit 4, it is not clear whether the replacement strainer design includes trash racks. Please identify whether the Turkey Point Unit 4 replacement strainer design includes a trash rack. If no trash rack is present, then please discuss whether TS 4.5.2.e.3 will be revised to remove the reference to a trash rack being present to be consistent with the current design of the Turkey Point Unit 4 sump.

RESPONSE

The Turkey Point Unit 4 replacement strainer design includes debris interceptors, which function much like trash racks. However, the Surveillance Requirement specifically refers to "sump components" and parenthetically refers to trash racks, screens, etc. as examples of sump components. The existing Unit 4 Technical Specification (TS) Surveillance Requirement 4.5.2.e.3 reads as follows:

> "[Each ECCS component and flow path shall be demonstrated OPERABLE: ...At least once per 18 months by:] A visual inspection of the containment sump and verifying that the suction inlets are not restricted by debris and that the sump components (trash racks, screens, etc.) show no evidence of structural distress or abnormal corrosion."

During FPL's preparation, review, and verification of the Generic Letter 2004-02 Supplemental Responses for Turkey Point Unit 4, this TS Surveillance Requirement and the corresponding Bases were reviewed to determine whether any changes were required or warranted. The FPL review determined that: 1) no change was required to the Surveillance Requirement, which requires the sump components to be inspected to show no evidence of structural distress or abnormal corrosion, and 2) the parenthetical phrase "(trash racks, screens, etc.)" was intended to represent examples of "sump components" to be inspected. FPL also determined that a formal License Amendment Request was not required and the explanation provided in the Bases (which were modified during the earlier Unit 3 review) sufficiently clarified this issue.

Therefore, the applicable TS Bases have been modified and read as follows:

> "Technical Specifications Surveillance Requirement 4.5.2.e.3 requires that each ECCS component and flow path be demonstrated OPERABLE every 18 months by visual inspection which verifies that the sump components (trash racks, screens, etc.) show no evidence of structural distress or abnormal corrosion. The strainer modules are rigid enough to provide both functions as trash racks and screens without losing their structural integrity and particle efficiency. Therefore, the strainer modules are functionally equivalent to trash racks and screens. Accordingly, the categorical description, sump components, is broad enough to require inspection of the strainer modules."

The revised Bases provide sufficient information to ensure that the sump components are inspected pursuant to the TS Surveillance Requirement. Based on the above discussion, FPL does not plan to revise TS Surveillance Requirement 4.5.2.e.3.

RAI 39
Page 30 of the August 11, 2008, supplemental response indicates that the replacement ECCS strainer design is a common, non-independent strainer assembly shared by both trains. The response indicates that this design is not a departure from the current licensing basis because the original ECCS sump intake design included a permanent cross-connection between trains that was located outside of containment. Please provide the following additional information concerning the original ECCS sump intake design:

RAI 39a
A piping system diagram that includes the cross-connection line between the ECCS sump suction lines.

RESPONSE
A portion of the requested Point Unit 4 plant drawing, 5614-M-3050 Sheet 1, is provided below in Figure 39-1 for the Residual Heat Removal System (RHR). The cross-tie valves 4-752A and 4-752B are shown as locked open, hence the current alignment and licensing basis is for a common suction cross-tie in this part of the system.

RAI 39b
A determination of whether the original ECCS sump suction lines were normally isolated, independent lines during sump recirculation mode that could be cross-connected by operator action, or whether the cross-connect was normally open in recirculation mode.

RESPONSE
The 1964 Turkey Point Unit 3 & 4 Preliminary Safety Analysis Report (PSAR) Revision 0, Chapter 6, Figure 6-1, "Safety Injection System" shows in the Unit 3 Figure that these same RHR System cross-tie valves are in the locked-open position per the original design. This Unit 3 Figure is also applicable to Unit 4. Also, PSAR Supplement 2 gives a response to the AEC (NRC) on Question 9.2, wherein a Figure 9.2-1, "Safety Injection and Spray System," shows the same cross-tie valves locked open. This confirms that the original ECCS sump suction lines to the RHR pumps were configured in a cross-tied arrangement with the cross-tie valves in the locked-open position for the recirculation mode.

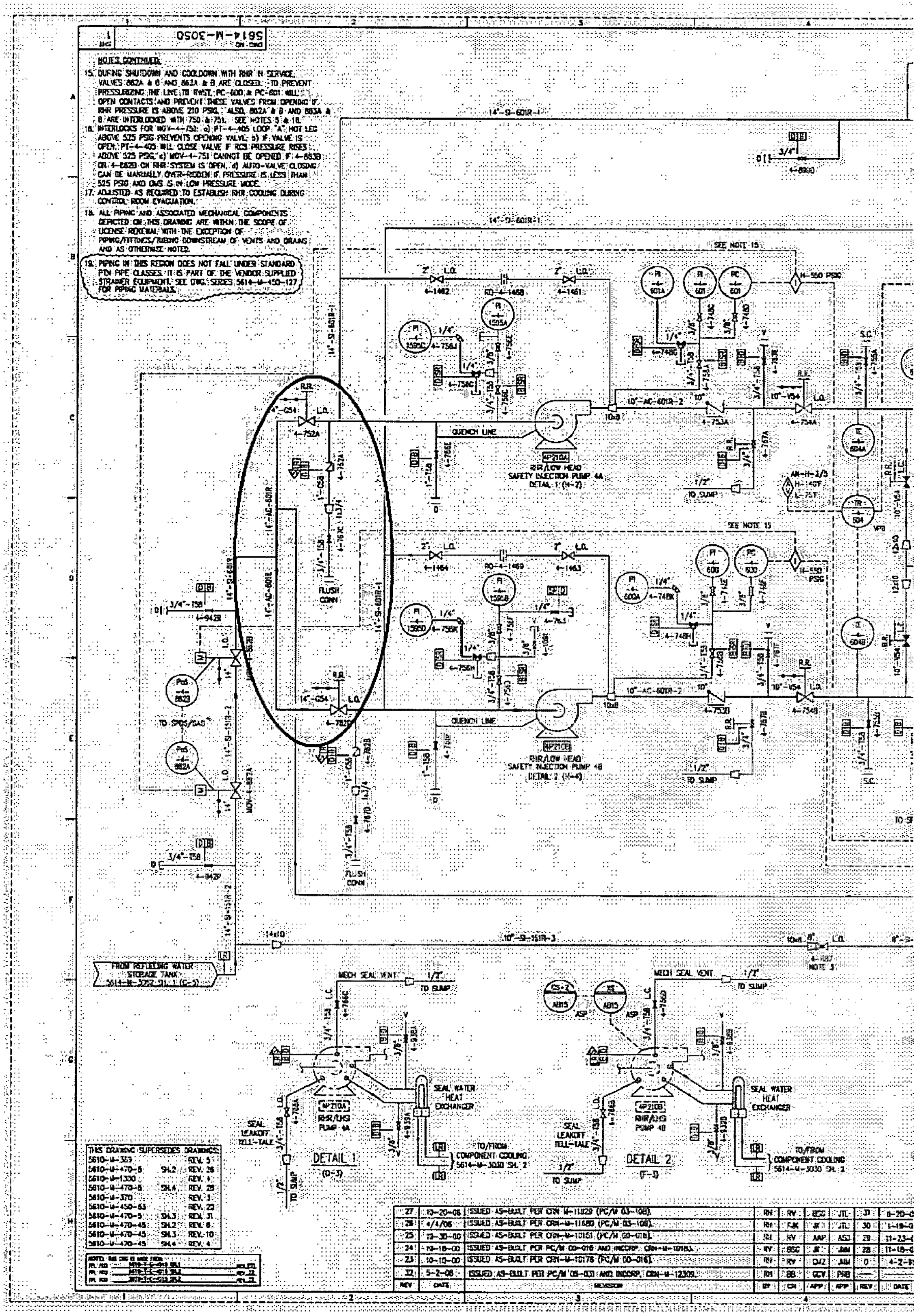
RAI 39c
The type of valves installed on the cross-connect line (if any), and whether remote or manual operation would be necessary to operate the valves.

RESPONSE
The subject cross-tie valves discussed above are manually operated, locked-open gate valves provided with reach rods in the event that remote manual operation is desired.

RAI 39d
A justification of any change to the plant licensing basis that would be necessary if the independence of the original sump screens was reduced. Please note that if the cross-connection line was a normally isolated line during recirculation, then this would indicate that the original ECCS sump screens were independent screens that could be shared if desired during an event, which is a different configuration than the current replacement strainer design that does not have independence.

RESPONSE

See above responses. The Turkey Point plant licensing basis is maintained with the new sump screen design since the original ECCS sump suction lines to the RHR pumps were configured in a cross-tied arrangement with the cross-tie valves in the locked-open position.



NOTES CONTINUED:

15. DURING SHUTDOWN AND COOLDOWN WITH RHR IN SERVICE, VALVES 862A & B AND 863A & B ARE CLOSED. TO PREVENT PRESSURIZING THE LINE TO RWST, PC-600 & PC-601 WILL OPEN CONTACTS AND PREVENT THESE VALVES FROM OPENING IF RHR PRESSURE IS ABOVE 210 PSIG. ALSO, 862A & B AND 863A & B ARE INTERLOCKED WITH 750 & 751. SEE NOTES 5 & 16.
16. INTERLOCKS FOR MOV-4-752: a) PT-4-405 LOOP "A" HOT LEG ABOVE 525 PSIG PREVENTS OPENING VALVE; b) IF VALVE IS OPEN, PT-4-405 WILL CLOSE VALVE IF RCS PRESSURE RISES ABOVE 525 PSIG; c) MOV-4-751 CANNOT BE OPENED IF 4-863B OR 4-862B ON RHR SYSTEM IS OPEN; d) AUTO-VALVE CLOSING CAN BE MANUALLY OVER-RIDDEN IF PRESSURE IS LESS THAN 525 PSIG AND OMS IS IN LOW PRESSURE MODE.
17. ADJUSTED AS REQUIRED TO ESTABLISH RHR COOLING DURING CONTROL ROOM EVACUATION.
18. ALL PIPING AND ASSOCIATED MECHANICAL COMPONENTS DEPICTED ON THIS DRAWING ARE WITHIN THE SCOPE OF LICENSE RENEWAL WITH THE EXCEPTION OF PIPING/FITTINGS/TUBING DOWNSTREAM OF VENTS AND DRAINS AND AS OTHERWISE NOTED.
19. PIPING IN THIS REGION DOES NOT FALL UNDER STANDARD PTN PIPE CLASSES. IT IS PART OF THE VENDOR SUPPLIED STRAINER EQUIPMENT. SEE DWG. SERIES 5614-M-450-127 FOR PIPING MATERIALS.

| THIS DRAWING SUPERSEDES DRAWINGS: | | |
|---|---|---|
| 5610-M-369 | | REV. 5 |
| 5610-M-470-5 | SH.2 | REV. 36 |
| 5610-M-1300 | | REV. 4 |
| 5610-M-470-6 | SH.4 | REV. 28 |
| 5610-M-370 | | REV. 3 |
| 5610-M-450-53 | | REV. 22 |
| 5610-M-470-5 | SH.3 | REV. 31 |
| 5610-M-470-45 | SH.2 | REV. 8 |
| 5610-M-470-45 | SH.3 | REV. 10 |
| 5610-M-470-45 | SH.4 | REV. 4 |

| REV | DATE | REVISION | BY | CH | APP | APP | REV | DATE |
|---|---|---|---|---|---|---|---|---|
| 27 | 10-20-06 | ISSUED AS-BUILT PER CRN-M-11829 (PC/M 03-108). | RH | RV | BSG | JTL | 31 | 6-20-0 |
| 26 | 4/4/06 | ISSUED AS-BUILT PER CRN-M-11680 (PC/M 03-108). | RH | FJK | JK | JTL | 30 | 1-19-0 |
| 25 | 10-30-00 | ISSUED AS-BUILT PER CRN-M-10151 (PC/M 00-016). | RH | RV | AAP | ASJ | 29 | 11-23- |
| 24 | 10-18-00 | ISSUED AS-BUILT PER PC/M 00-016 AND INCORP. CRN-M-10183. | RV | BSG | JK | JAM | 28 | 11-18-0 |
| 23 | 10-10-00 | ISSUED AS-BUILT PER CRN-M-10178 (PC/M 00-016). | RH | RV | DJZ | JAM | 0 | 4-2-9 |
| 32 | 5-2-08 | ISSUED AS-BUILT PER PC/M 05-033 AND INCORP. CRN-M-12309. | RH | BB | CCV | PSB | — | — |

FIGURE 39-1 RESIDUAL HEAT REMOVAL SYSTEM