Florida Power & Light Company, 6501 S. Ocean Drive, Jensen Beach, FL 34957

FPL

April 16, 2009

L-2009-085
10 CFR 50.54(f)

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
Rockville, Maryland 20852

Florida Power & Light Company
St. Lucie Unit 2
Docket No. 50-389

Subject: Response to NRC Request for Additional Information

References: (1) Letter from S. P. Lingam (U. S. Nuclear Regulatory Commission) to M. Nazar (FPL), "St. Lucie Unit 2 – 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. MC4711)" dated January 16, 2009 (ML083658978)

(2) Letter L-2008-030 from G. L. Johnston, (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 27, 2008 (ML080650560)

(3) Letter L-2008-137 from G. L. Johnston, (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 June 30, 2008 (ML081840513)

(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

This submittal provides the Florida Power and Light Company (FPL) responses to the U. S. Nuclear Regulatory Commission's (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 responses for St. Lucie Unit 2 to the request for additional information (RAI). This information is being provided in accordance with 10 CFR 50.54(f).

A116
NRR

Please, contact Mr. Ken Frehafer at (772) 467-7748 if you have any questions regarding this response.

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

Executed on April 16, 2009.

Sincerely yours,

Christopher R Castanzo for SVP

Gordon L. Johnston
Site Vice President
St. Lucie Plant

GLJ/KWF

Attachment: (1)

Attachment 1

St. Lucie Unit 2

Individual Responses to NRC RAIs for FPL Generic Letter GL 2004-02 Supplemental Responses, Dated 02/27/2008 and 06/30/2008

Introduction

Overview of St. Lucie Unit 2 (PSL2) Conservatisms:

FPL made significant improvements in the emergency core cooling system (ECCS) to address the issues identified in Generic Letter 2004-02. FPL included a number of conservatisms in the plant modifications and analyses to ensure sufficient margin is available. These margins are summarized below:

- The surface area for the recirculation sumps was increased from approximately 571 ft^2 to over 5600 ft^2. The replacement strainers were manufactured by Performance Contracting, Inc. and have a nominal hole size of 0.0625 inch compared to the previous screens' openings of 0.090 inch mesh size. Debris interceptors are in place at the entrance to the sump trench which further reduce the amount of debris that reaches the sump. These debris interceptors (trash racks) are distributed around 270 degrees of containment and are placed at each of 23 entrances to the containment trench system. This effectively prevents large debris from entering the sump trench from inside the biowall or approaching the strainers.

- Latent or miscellaneous debris was specifically accounted for in the design and testing of the strainer. Additionally, 100 square feet of sacrificial area was allotted for additional conservatism.

- In the debris generation analysis, the zone of influence (ZOI) used for Nukon Insulation is 17.0D. WCAP-16710-P testing confirmed that the ZOI could be reduced to 5D. As such, the strainer system was qualified utilizing a quantity of fiber 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.

- In the transport analysis, 100% of the unqualified coatings in the active pool were assumed to fail as particulates and transport to the screen. EPRI and industry testing indicates that some unqualified coatings do not fail and some coatings fail as chips and may not transport to the sump.

- 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 amount of chemicals calculated to form in 30 days were added to the test flume, and as such a 30 day chemical effect was applied in the early stages of the event. This is extremely conservative as corrosion and formation of chemical precipitants is a time base phenomena and significant additional NPSH margin is available as the containment pool temperature decreases over time.

The following responses to NRC RAIs provide another opportunity to discuss, in more detail, St. Lucie Unit 2 analyses and conservatisms. This information should facilitate NRC review and conclusion that St. Lucie Unit 2 design and analyses are conservative, and demonstrate that there is sufficient ECCS net positive suction head (NPSH) margin available as required by GL 2004-02.

RAI-1: Provide a basis or justification for assuming a 17.0D spherical ZOI for the FOAMGLAS® insulation.

RAI-1 RESPONSE: Design documents show the FOAMGLAS® insulation installed on several component cooling water lines supplying the reactor coolant pumps. This is anti sweat insulation made of glass manufactured by the Pittsburgh Corning company. This single application represents a very small fraction (approximately 6.6%) of the total amount of insulation debris generated within the containment building for the limiting break. Therefore, any variability in the effective ZOI would represent a very small variability in the overall debris generation totals.

ZOIs for commonly used insulation are provided in Table 3-1 of NEI-04-07 with final results provided in Table 3-2 of the NRC safety evaluation report (SER). The applicable ZOI radius is 17.0 D for Nukon and Knaupf (fiber) insulation, 5.45 D for calcium silicate insulation, 2.0 D for Transco RMI, and 28.6 D for Mirror RMI. There is no ZOI given for FOAMGLAS® insulation. FOAMGLAS® insulation is shown on drawings on specific component cooling lines in containment, and for the debris generation calculation, the ZOI for Nukon was used for FOAMGLAS®.

The Pittsburgh Corning company web site lists physical and thermal properties of FOAMGLAS®. The OEM product technical mechanical specification data sheets indicate the density to be approximately 7.5 lb per cu. ft. This is somewhat higher than the density taken for fiberglass blanket insulation (4 lb per cu. ft.) but within the same range.

The ZOI of 17.0 D is relatively large compared to ZOIs for most other materials and will envelope almost all FOAMGLAS® insulation inside the secondary biological shield (SBS) wall, and therefore is conservative. Considering the 17.0 D ZOI, margins added, and other conservatisms, only approximately 18 cu ft. of FOAMGLAS® is calculated to be generated for the worst case break.

RAI-2: For Nukon, calcium silicate, and foam glass debris, describe how 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. Provide the characteristic size of the fines for each type of debris (Nukon, calcium silicate, and foam glass)

RAI-2 RESPONSE: The small fines category of NEI 04-07 was divided into fine debris, individual fines, that will remain suspended in water and small pieces that would pass through a 1" x 4" grid. The sizing was based on guidance provided in the NEI 04-07 SER, and accounted for fine debris generated by eroding large debris into fine debris based on NUREG/CR-6808. The total quantity of fines was determined to be prototypical of plant conditions by utilizing industry guidance to divide and erode the total St. Lucie Unit 2 debris load into small and fine debris.

Small debris was prepared by dry shredding the insulation utilizing a shredder, and judged to pass through a 1"x4" grid. Fine debris was prepared by processing the small fibrous insulation dry in a food processor or similar device. The fibrous debris was mixed with water and stirred with a mechanical paddle prior to adding it to the test flume.

For St. Lucie Unit 2 calcium silicate powder was utilized. This characteristic size is the most conservative with respect to debris transport and head loss as stated in NEI 04-07, Volume 1, paragraph 3.4.3.6 and Table 3-2.

The quantity of FOAMGLAS® is small relative to the overall quantity of fiber debris, 556.35 ft^3. Also, the FOAMGLAS® will float indefinitely. The water vapor permeability is 0. The water vapor absorption is 0.2 %. The only water vapor retained is that adhering to the surface cells after immersion. The manufacturer was contacted to verify that the technical data was interpreted correctly. The technical representative for the manufacturer confirmed that the FOAMGLAS® would float. He described the product as spheres of gas impregnated in glass. Because FOAMGLAS® will float indefinitely; it will not collect on the strainers and will not contribute to the head loss across the strainers.

RAI-3: Describe the statistical methodology used to compute the sample mass used in the estimates of total latent debris mass.

RAI-3 RESPONSE: The calculation of latent debris derived a conservative estimate of the total mass of latent debris inside the St. Lucie Unit 2 containment based on the postulated events set forth in GSI-191. The derivation was based on the observation and measurement of dust and lint inside the Unit 2 containment. A containment walkdown was performed to collect latent debris samples from the plant surfaces listed in Table 3-1 below. As stated within section 3.5.2.2 of the NRC SER of NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology", Volume 2, Revision 0, December 6, 2004, a minimum of three (3) samples of each surface type were required. However, to conservatively increase statistical sampling accuracy and to provide redundancy for discrepant samples, a minimum of four (4) samples were collected from each surface type. A total of forty eight (48) samples were collected.

Table 3-1
Plant surface Types
Horizontal concrete surfaces (floors) Vertical concrete surfaces (walls) Grated surfaces at support beams Containment liner (vertical) Cable trays (vertical) Cable trays (horizontal) Horizontal equipment surfaces (heat exchangers, air coolers, etc.) Vertical equipment surfaces (steam generators, air coolers, pressurizer, etc.) Horizontal heating, ventilation and air conditioning (HVAC) duct surfaces Vertical HVAC duct surfaces Horizontal piping surfaces Vertical piping surfaces (pipes running vertically)

In probability and statistics, the t-distribution or Student's t-distribution is a probability distribution function used for conservatively estimating the mean of a normally distributed population when the sample size is by necessity small compared to the population size. The t-distribution methodology successfully solves the mathematical problems associated with inference based on small samples where the calculated mean (x_m) and calculated standard deviation (s) may by chance deviate from the actual mean and actual standard deviation (i.e., what you would measure if you had many more data items: a larger number of samples). As a result, the t-distribution statistical approach is best suited for conservative derivation of the amount of latent debris that has accumulated in the containment.

An upper tailed t-distribution value of 1.638 for a 90% confidence level was selected and used for statistical evaluation of each containment surface type containing four (4) samples. Selection of the 90% confidence level upper-tailed t-distribution values cited above is technically robust and appropriate for this application based on the walkdown team's inspection and observation that each containment surface type appeared to have a normal distribution of dirt and lint. Additionally, each sample location was randomly selected by the inspection team.

The debris sample data was analyzed to estimate the total latent debris mass. The samples were grouped by surface type (i.e., vertical equipment, horizontal cable tray, etc.). These represent random samples (n) of the total population of areas. The sample mean (x_m) and the sample standard deviation (s) were determined for the debris mass found per unit area.

$$x_m = \sum x_i / n \qquad \text{(Eq. 3-1)}$$

$$s^2 = [\ 1 / (n-1)\ ] * [\ \sum x_i^2 - (\ \sum x_i)^2 / n\ ] \qquad \text{(Eq. 3-2)}$$

Where:
x_m is the mean for a group of samples (gm/ft^2)
x_i is the individual mass per area (gm/ft^2)
n is the number of samples in the group
s is the sample standard deviation

Assuming the latent debris (dust and lint) were normally distributed as indicated by observation, and the number of samples is small relative to the total population, an upper limit on the mean debris loading (u_{ul}) was determined from the t-distribution. Use of the 90% confidence level means there is a 90% probability that the actual mean latent debris loading (u) is less than or equal to u_{ul}.

$$x_m - t_{ul} * s * (n)^{-1/2} < u < x_m + t_{ul} * s * (n)^{-1/2}$$

$$u_{ul} = x_m + t_{ul} * [\ s * (n)^{-1/2}\ ] \qquad \text{(Eq. 3-3)}$$

Where:
t_{ul} is the upper-tailed t-distribution value at 90% confidence for sample size n
u_{ul} is the upper limit on the mean debris loading at 90% confidence (g/ft^2)

To estimate the total debris mass for a surface type, u_{ul} is multiplied by the total area for that surface type. The total latent debris mass is then the sum of the derived values for each surface type.

RAI-4: Provide the accuracy of the individual sample mass measurements and the influence of the uncertainty on the total computed mass of latent debris.

RAI-4 RESPONSE:

Sample Mass Measurement Accuracy

The walkdown plan specified that a scale with an accuracy of at least 0.1 grams was to be used to measure the weight of each latent debris sample. The actual scale accuracy was determined to be 0.0004 grams.

Influence of the Uncertainty in the Samples

Masslin cloths were used to obtain the latent debris samples. Plastic bags were used to store the Masslin cloths with each latent debris sample. Prior to the walkdown, the mass of each plastic bag with the Masslin cloth inside was measured. Following the walkdown, the mass of each sample (plastic bag with Masslin cloth and latent debris) was measured utilizing the same scale that was used for the pre-walkdown measurements. Each net latent debris sample mass was obtained by taking the difference between the post-walkdown and pre-walkdown sample masses.

The uncertainty associated with the difference of two values is equal to the sum of the uncertainties associated with each value. The minimum latent debris sample mass was 0.05 grams. Based on a scale accuracy of 0.0004 grams, the maximum data uncertainty is estimated to be 1.6%. The average data uncertainty is estimated to be less than 0.2%.

RAI-5: Describe in more detail the methodology used to estimate the total area of tapes, stickers, and miscellaneous debris. Include any assumptions that would reduce the quantity of material transported to the sump screen.

RAI-5 RESPONSE: Containment walkdowns were performed to identify and measure plant labels, stickers, tape, tags, and other debris in accordance with the guidelines in the walkdown plan. Equipment tags located in containment will become debris, unless they are located outside the ZOI of the postulated pipe break and are qualified for the post loss of coolant (LOCA) environment. Therefore, post LOCA qualified equipment tags located outside the ZOI (attached by wire, threaded fastener, rivets or qualified tie wraps) are not counted as debris.

Accessible containment areas were examined during the walkdown. Stickers, labels and other debris were quantified, measured and recorded on the foreign material record sheets. All miscellaneous or non-recurring items were captured individually. Several types of labels and stickers were found consistently on certain plant structures and equipment throughout containment and were measured. The total number of light bulbs in containment lighting was established by drawings, specifications or equipment lists as applicable.

It was observed that many items, such as junction boxes, conduits, and cable trays were marked with paint rather than a label or sticker and therefore would not create any foreign debris. Other items such as post LOCA qualified conduit labels (metal tags attached by metal wire or rivets) will not become debris following a GSI-191 pipe break unless they are located in the ZOI. The specific items that could potentially become foreign debris are discussed below.

Light Bulbs

Lighting is located throughout containment and primarily consists of a metal fixture that is a hemisphere opening toward the floor containing a light bulb enclosed by a protective heavy glass cylinder. The light bulbs are standard industrial size and were modeled as a 4" diameter sphere. The protective glass covering was conservatively modeled as an open-end cylinder that is 8" long with a 4.5" diameter hemisphere. The metal fixtures would not be affected by containment spray or elevated containment pressure during a GSI-191 event and would not become transportable debris due to a pipe break. Light bulbs can potentially break and become debris during post LOCA conditions due to the increased pressure inside containment. However, the protective glass cylinder enclosures will not break due to elevated containment pressure because they are not air tight (elevated containment pressure will equalize across the inner and outer glass surfaces). As a result, the protective light bulb glass enclosures will capture and contain any broken or shattered light bulb glass. However, containment lighting located in the ZOI will break and potentially contribute debris loading to the containment sump. Conservative evaluation of plant lighting in the ZOI at the 18' elevation of containment (including platforms in this location) determined that 34 plant lights will become debris during a GSI-191 event.

Adhesive

Adhesive residue was found at numerous locations throughout the plant. Based on walkdown observations and discussion with plant personnel, a significant number of various signs have been removed inside containment with adhesive residue remaining behind in many areas. The adhesive is usually very thin and 1/32" was used as the adhesive thickness to determine the total volume of adhesive (except for ten (10) 10" x 0.75" patches of adhesive found on containment walls at elevation 62' - 0"). It was conservatively assumed that all adhesive will become debris during LOCA conditions.

Equipment Tags

Equipment inside St. Lucie Unit 2 containment is labeled with a 4" x 2.25" hard plastic tag. The tag is attached to equipment by metal wire. Equipment tags attached by metal wire will not become debris outside the ZOI. Equipment tags that are within the ZOI will become debris during a LOCA. As a result, equipment tags were counted in the ZOI of one loop (Loop B) to determine the total number of equipment tags that would become debris during a LOCA. A total of approximately thirty five (35) tags were counted in the ZOI. For conservatism, fifty (50) was used as the total number of equipment tags that will become debris inside the ZOI during a LOCA.

Miscellaneous

Tape and stickers are located throughout containment and were individually counted during the walkdown.

Results

Based on the walkdowns, containment foreign material debris totals were tabulated. These materials are assumed to become available for transport to the containment sump during a postulated LOCA. A 10% margin was added to the label, sticker, tape, placards, etc. total to account for areas of containment that were inaccessible during the walkdown due to high dose rate or ongoing work activities.

No assumptions were made that would reduce the quantity of foreign debris material transported to the sump screen.

RAI-6: Provide a contour plot of the velocity for the containment pool inside the bioshield wall. Provide a contour plot of the velocity in the emergency core cooling system (ECCS) trench. Provide a close-up plot of the velocity and turbulence contours in the region of the strainer and its immediate vicinity. 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.

RAI-6 RESPONSE: The contour plots, Figures 6-1 through 6-8, requested are shown 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. Tables 6-1 (LPSI failure to trip case) and 6-2 (Design Flow case), test flume velocity vs. distance from strainer module, are also shown below.

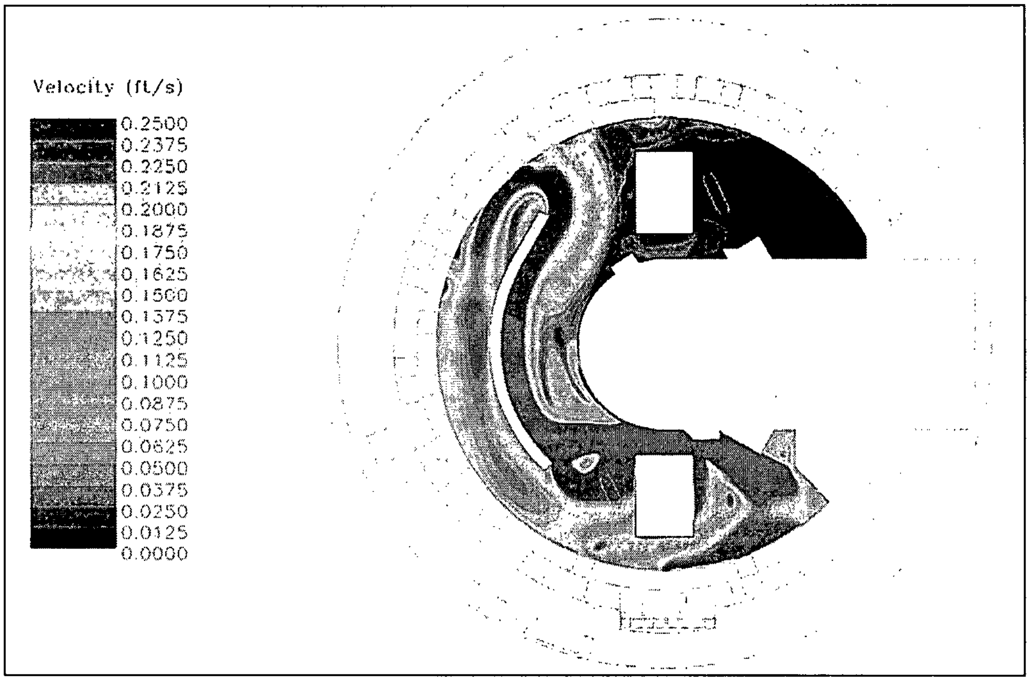


Figure 6-1 Plot of velocity contour inside bioshield wall. High Flow

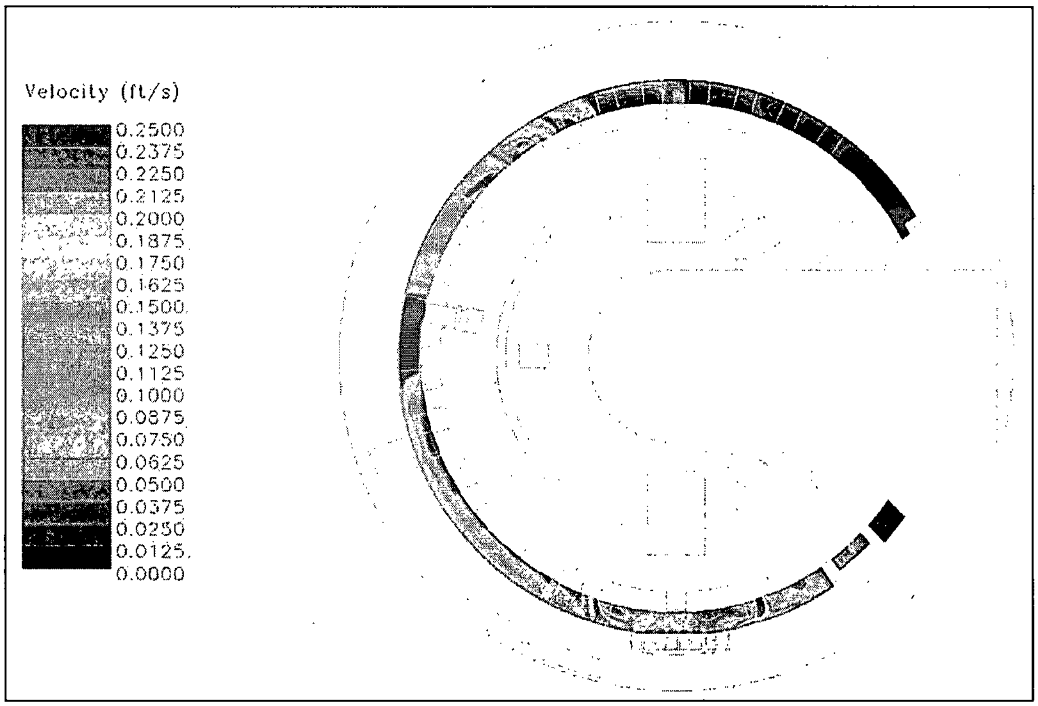


Figure 6-2 Plot of velocity contour in the trench. High Flow

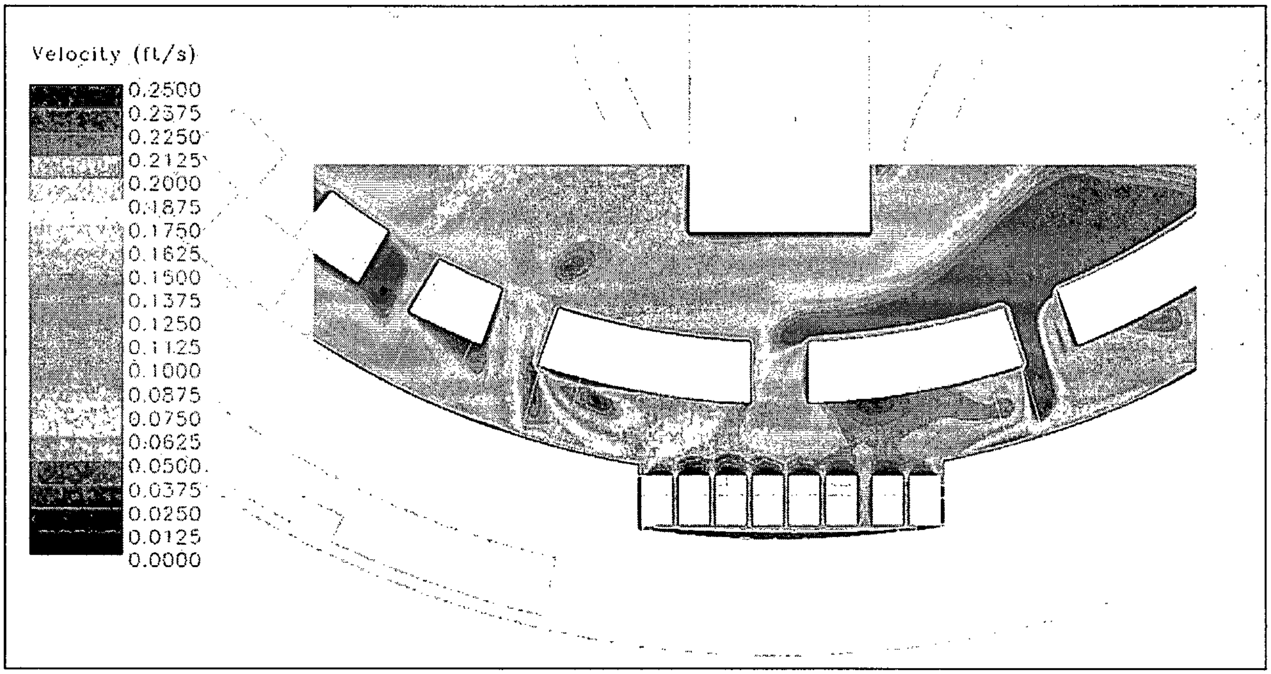


Figure 6-3 Plot of velocity contour within 20 feet from the strainer. High Flow

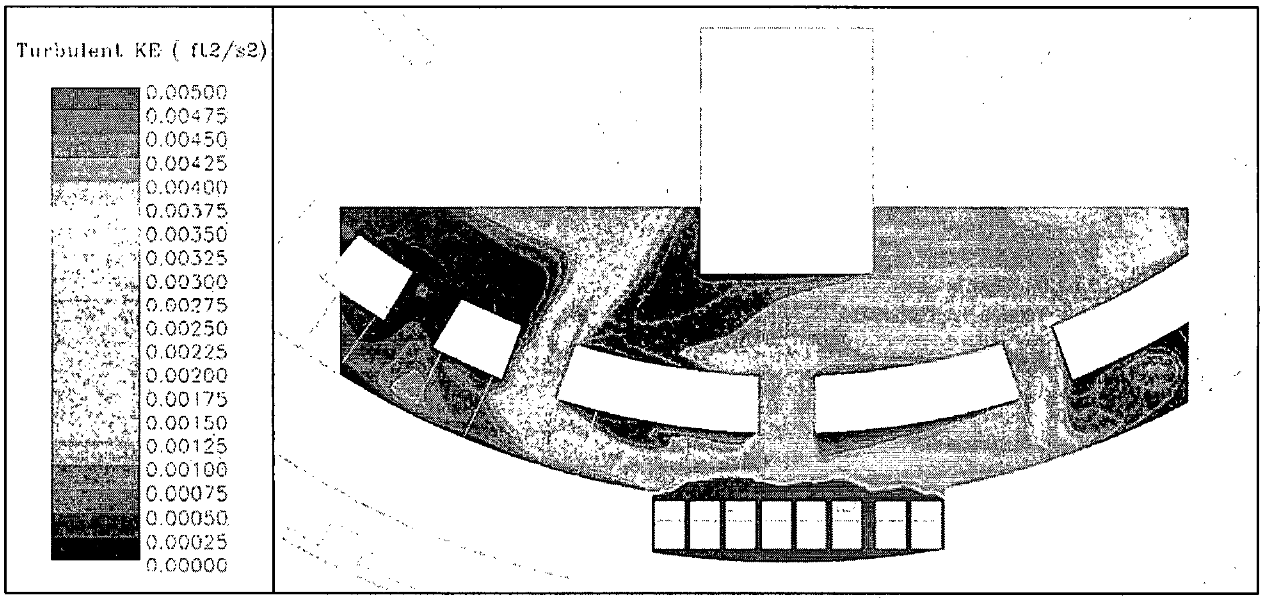


Figure 6-4 Plot of turbulent kinetic energy contour within 20 feet from the strainer. High Flow

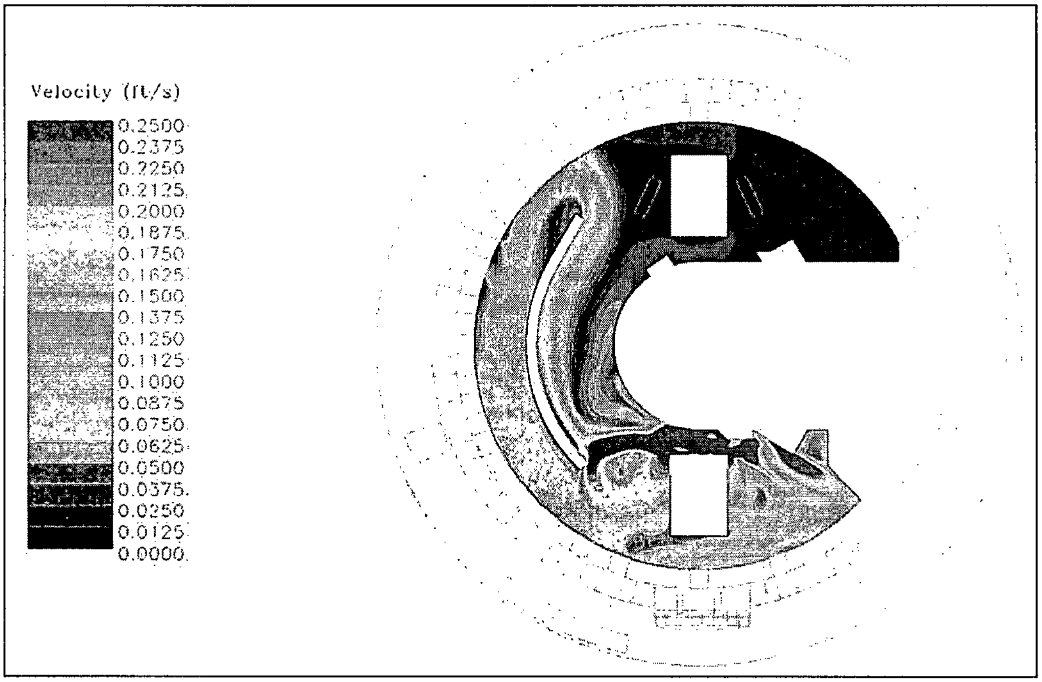


Figure 6-5 Plot of velocity contour inside bioshield wall. Low Flow

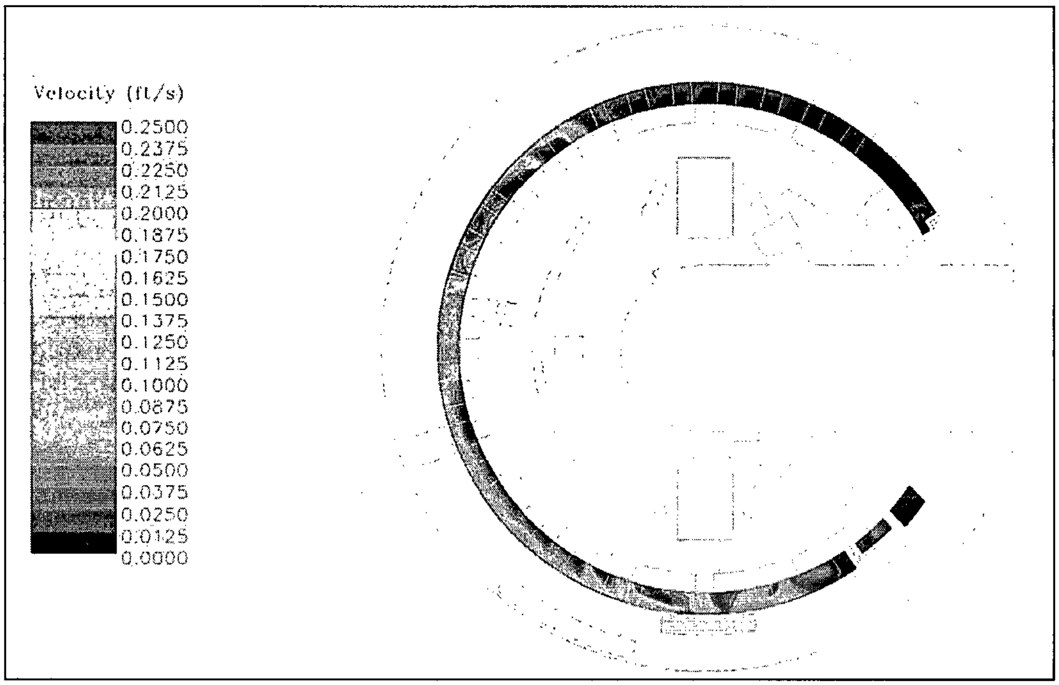


Figure 6-6 Plot of velocity contour in the trench. Low Flow

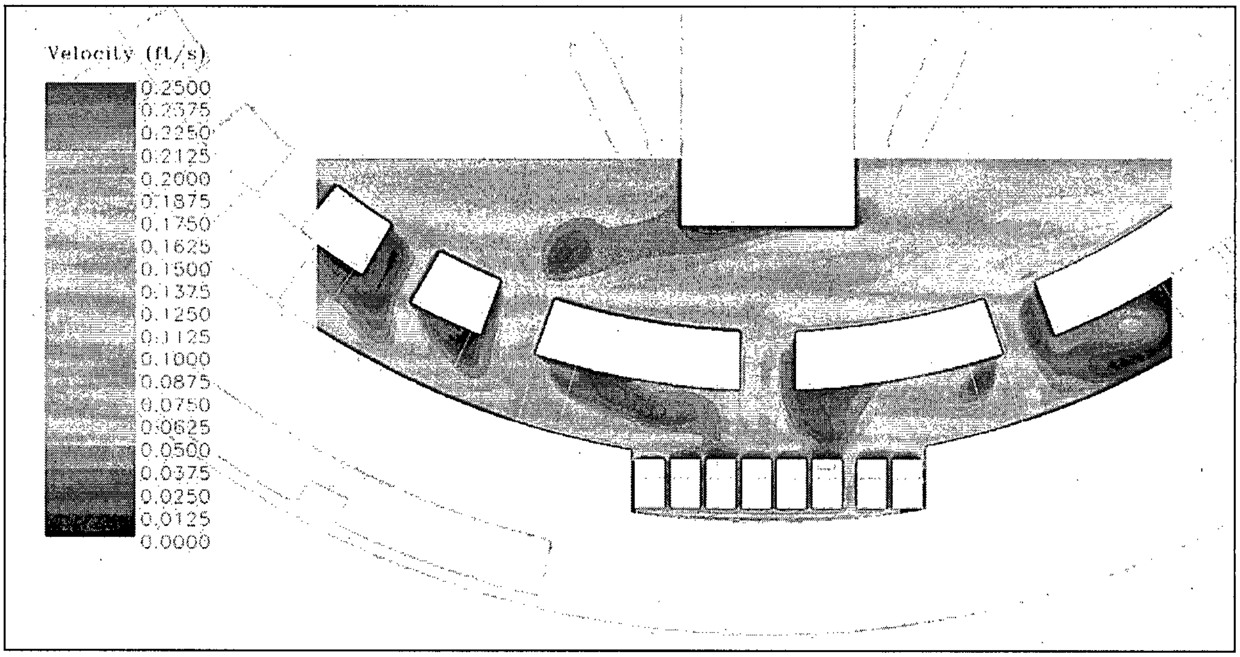


Figure 6-7 Plot of velocity contour within 20 feet from the strainer. Low Flow

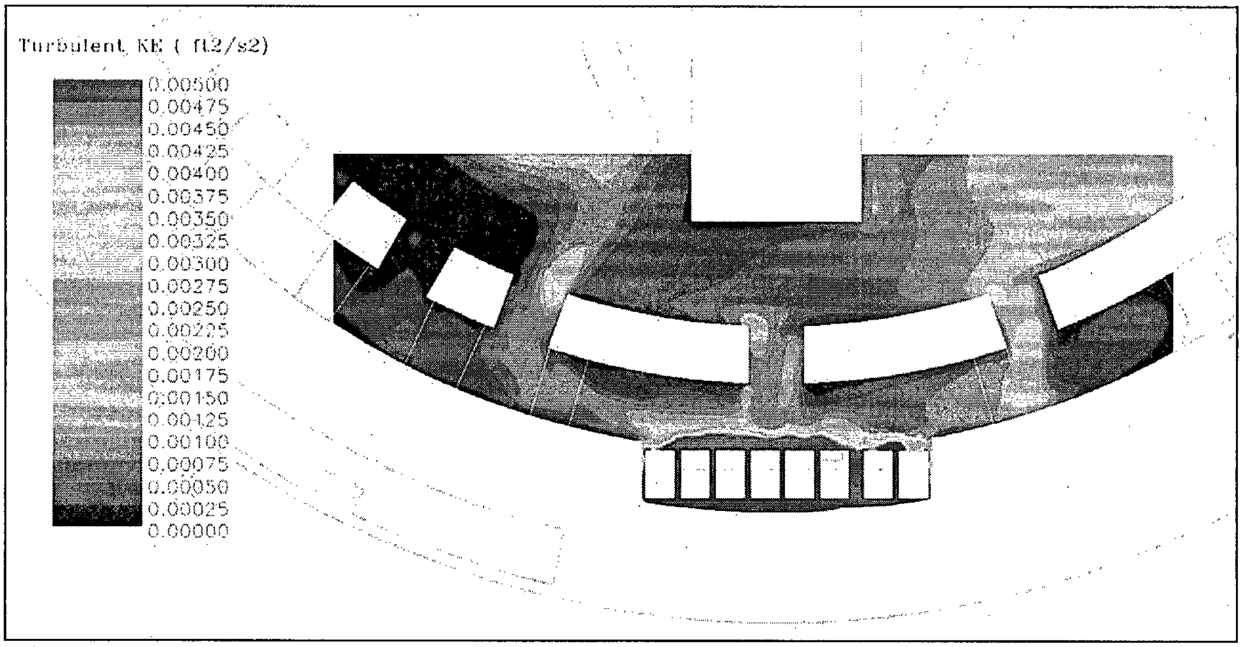


Figure 6-8 Plot of turbulent kinetic energy contour within 20 feet from the strainer. Low Flow

Table 6-1

Approach Velocity for LPSI failure to Trip (Total Sump Flow = 8570 GPM)	
Distance from Strainer (ft)	Average Velocity (ft/s)
1	0.1719
2	0.1744
3	0.1770
4	0.1795
5	0.1849
6	0.1890
7	0.1930
8	0.1971
9	0.1880
10	0.1802
11	0.1725
12	0.1647
13	0.1726
14	0.1805
15	0.1885
16	0.1965
17	0.1668
18	0.1427
19	0.1408
20	0.1389
21	0.1376
22	0.1507
23	0.1638
24	0.1769
25	0.1900
26	0.1927
27	0.1952
28	0.1999
29	0.1965
30	0.1932

Table 6-2

Approach Velocity for Design Flow (Total Sump Flow = 4970 GPM)	
Distance from Strainer (ft)	Average Velocity (ft/s)
1	0.1083
2	0.1099
3	0.1115
4	0.1131
5	0.1165
6	0.1190
7	0.1216
8	0.1241
9	0.1184
10	0.1135
11	0.1087
12	0.1038
13	0.1087
14	0.1137
15	0.1187
16	0.1238
17	0.1051
18	0.0899
19	0.0887
20	0.0875
21	0.0867
22	0.0949
23	0.1032
24	0.1114
25	0.1197
26	0.1214
27	0.1230
28	0.1259
29	0.1238
30	0.1217

RAI-7: Describe how the ECCS trench was modeled in the computational fluid dynamics (CFD) calculation, including the modeling of the various flows into the trench and the presence of obstacles in the trench, such as piping, tanks, Trisodium Phosphate Dodecahydrate (TSP) baskets, and other equipment.

RAI-7 RESPONSE: GAMBIT Version 2.1.6 was used to generate three dimensional solid models of the containment building from the floor elevation to the selected water surface elevation. GAMBIT was also used to generate the computational mesh and to define boundary surfaces required to perform the CFD analysis. The ECCS trench model included the drain tank. However, the model did not include relatively small objects, such as support columns, pipes, pipe supports, equipment, instrument panels, and etc., which are less than six inches along their longest dimension. Groups of objects with projected dimension greater than six inches were included. Where critical areas such as containment sumps and constricted flow paths exist, objects less than six inches were included. Fluent version 6.1.22 was used to perform the CFD simulations to determine the flows.

RAI 8: Provide the general methodology used to determine the average flow to the strainer modules. In doing so, provide added detail concerning how the flow velocity in the ECCS trench approaching the modules from each side of the modules was "averaged" with the flow approaching from the shield wall openings in front of the modules. Identify the "four flow streams" discussed on page 20 of the supplemental response.

RAI-8 RESPONSE: The calculation of the St. Lucie Nuclear Power Plant Unit 2 (PSL2) Sure Flow Strainer qualification test program flume configuration utilizes the results of the CFD debris transport study to define the average approach velocities to the strainer. The following methodology is applied:

Numerically seed each active module train face with massless tracer particles (massless tracer particles show the direction of the flow at every point along their path) and back-calculate the trajectory of the particles to define streamline traces to each module. This identifies the path the water follows to each strainer module face. With the water path to each module identified, define vertical planes at 1 ft increments back from the each module train, along the paths defined by the streamlines. Trim each plane such that the velocities within that plane are those which convey water to the module. At each 1 ft increment back from the module train, record the cross section average of the velocity across that plane. If the paths diverge around objects in the flow, follow each bifurcated path individually. Subsequently, calculate the weighted average of the four flow streams at each 1 ft increment. The average at each increment is weighted by twice the fastest velocity at the increment under consideration. Weighting the average by twice the fastest velocity incorporates conservatism into the calculation. Create a plot of the calculated weighted average velocity vs. incremental distance back from the module train. Calculate the width of the test flume at each line segment break using the expression for continuity Q = AV where Q is the test module flow, A is the cross sectional area defined by the water height and the flume width and V is the velocity. With this information, a table of flume width vs. line segment length to be used in defining the shape of the flume is created.

The four flow streams are the flow paths to the strainer. Refer to Figure 8-1 below. The flow approaches the strainer from four directions, from the trench on each side of the strainer and from the two nearest openings in the SBS wall.

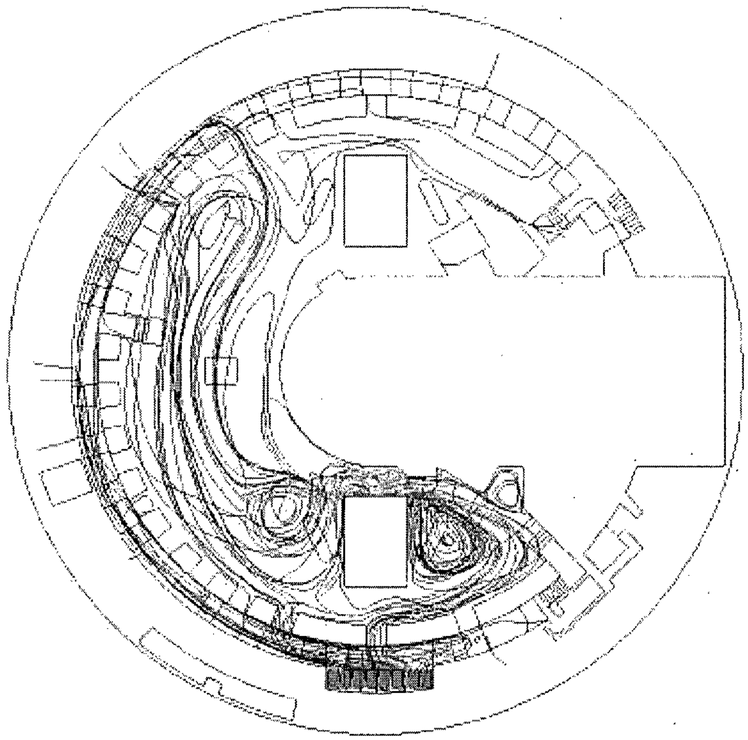


Figure 8-1: Streamlines for Scenario: Particles Released from Sump

Computations were prepared for flow paths at one foot intervals thirty feet back from the strainer. There were up to five flow paths depending on the distance from the strainers. The four flow paths are the primary flow paths near the strainer.

RAI-9a: Provide the following additional information needed to support the assumption of 10% erosion of fibrous debris in the containment pool:

Demonstrate the similarity of the flow conditions (velocity and turbulence), chemical conditions, and fiberglass material present in the erosion tests to the analogous conditions applicable to St. Lucie 2.

RAI-9a RESPONSE: Fiber erosion testing was performed by Alion Science and Technology (Alion) and documented in a final report. This test conservatively determined a 10% erosion of fibrous debris in the containment pool over the thirty day mission time. St. Lucie Unit 2 Low Density Fiberglass Debris Erosion Testing Report compared the testing performed to specific St. Lucie Unit 2 fiberglass insulation materials, and flow conditions and concluded that the testing conservatively bounded the St. Lucie Unit 2 design parameters.

Testing utilized Nukon, a low-density fiberglass insulation material manufactured by Performance Contracting, Inc. The insulation was procured in large sheets and cut and/or shredded in order to accommodate any particular use. Two sizes of Nukon low density fiberglass insulation were tested: Large samples measuring 6"x3"x1" weighing approximately 10 to 20 grams per sample, and small samples in which each sample was a collection of 8-12 clumps of 1"x1"x1" shredded fiberglass weighing approximately 4 to 6 grams total per sample. These small clumps that formed the sample were arranged such that each clump would be exposed to the same flow rate.

After the formation of each sample, they are boiled in tap water for over 10 minutes in order to remove the binder. Such boiling envelopes the conditions that the fiber would undergo during the blow down and recirculation phases of post LOCA responses at St. Lucie Unit 2. The erosion tests were conducted at room temperature, and this temperature was recorded with each data point. The increased post LOCA water temperature at St. Lucie Unit 2 would have little effect on the flow erosion of fiberglass with respect to water density and viscosity differences. The lack of containment recirculation chemicals and neutral pH of the tap water would also have little effect on the flow erosion mechanism. Chemicals such as aluminum that would be present in containment would actually coagulate on the fibers and increase the weight of the fiber pieces as opposed to aiding its erosion.

Erosion tests were performed at a flow velocity that is equal to the incipient tumbling velocity for the specific size. These flow velocities, determined in NEI 04-07 are 0.37 ft/s for large sample pieces and 0.12 ft/s for the small sample pieces. Since the incipient tumbling velocity is the velocity at which the debris would start moving, this velocity bounds the greatest velocity that a piece of insulation lying in the containment pool would experience without being carried to the sump strainer. It also bounds any lesser flows that might be found in the St. Lucie Unit 2 pool. Therefore, it is considered the velocity that would produce the most insulation fines that would travel to the sump strainer while the piece of insulation itself remains stationary in the pool.

St. Lucie Unit 2 contains Nukon/Knaupf fiber debris. Alion's erosion test reports used Nukon samples of the same density as the St. Lucie Unit 2 Nukon, Knaupf, LDFG materials. Based on this density similarity Nukon served as the surrogate for erosion testing for these materials.

RAI-9b: Provide the following additional information needed to support the assumption of 10% erosion of fibrous debris in the containment pool:

Identify the length of the erosion tests and how the results were extrapolated to the sump mission time.

RAI-9b RESPONSE: The small Nukon samples generally eroded more than the large samples, despite the large samples undergoing a higher flow velocity. The highest large sample erosion value of approximately 6% at 48 hours is approximately the average of the small samples for all erosion durations. The extra large sample (6"x6"x1") flow eroded at a velocity of 0.37 ft/s also eroded less than the large and small samples for the corresponding duration—2.35% of initial weight compared to an average of 4.32% and 4.48% for large and small at 8 hours, respectively. Small samples erode more weight due to the increased surface area and the preparation by shredding, which produces more fines available for flow erosion. Because the small samples erode more than the large samples, the analysis of the data only concerned the small samples. This method of data analysis yielded the most conservative fiber erosion results and the higher results for the small samples were conservatively applied to all of the fiber, large and small.

Tests were performed for a variety of durations both in vertical test loop and test flume configurations. Durations included were from 2 to 737 hours. No extrapolations were performed since percent mass changes for longest durations were not necessarily the largest. To be conservative, all of the larger percent mass changes were included in the evaluation, regardless of duration.

Because the erosion of LDFG has yielded scattered results across all erosion durations, a reasonable supposition was to hypothesize that the erosion is not directly time-dependent, and can be accurately described by averaging all of the erosion values against one another to reach an erosion value. After 737 hours of erosion, all of the fiber pieces or fines that will wash off at the constant 0.12 ft/s flow velocity already have, and to find an appropriate erosion value for all small fiber pieces, the average of all small sample erosion data will be applicable to a 30 day mission time.

The average of the weight loss values of the tests is 5.93% ±4.37% of initial weight using RMS error analysis versus the calculated average. This averaging methodology estimates that the fiber erosion rate at 30 days can be conservatively estimated as 5.93% + 4.37% ≈ 10% of initial fiber weight. The attrition/erosion mechanism that strips away the loose pieces of LDFG via flowing water would reduce an initial amount of fiber by 10% over 30 days.

RAI-10: Describe how the kinetic energy of the containment sprays entering the containment pool was modeled. This flow splashing down 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 at the containment pool elevation (as is assumed for St. Lucie Unit 2) due to non-uniformities in the structures at higher elevations (e.g., refueling canal drains, hatch openings, gaps in curbs, etc.). Provide the justification for using a uniform spray drainage model.

RAI-10 RESPONSE: Turbulent kinetic energy was specified at the water surface where the water from the sprays is assumed to enter the pool. Spray flow is introduced into the containment building from spray headers located in the upper containment. The water from these sprays travels to the pool through all available openings at each elevation. In the St. Lucie Unit 2 containment, the path from the upper containment to the pool is generally inside and outside the secondary bio shield wall. The operating floor of containment is generally concrete to a radius of 56'. From a radius of 56' to 68' – 2" the floor is generally grating. However, there are numerous openings in the concrete around components such as the steam generators. Although it is acknowledged that the flow distribution will not be even, the tortuous path from the upper elevations to the containment sump will break up streams of water flowing downward. 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.

RAI-11: The supplemental response states on page 14 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 given zones in the containment pool. 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:

a. 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. 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.

b. 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.

c. 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.

RAI-11 RESPONSE: For the transport calculation performed for St. Lucie Unit 2, while the provision was stated that isolated eddies with velocities higher than the incipient tumbling velocity would not contribute to transport, upon further review of the detailed transport calculations, there were no isolated eddies identified and, thus, no such credit was taken in the transport analysis. If the results of the CFD predicted flow rates higher than the incipient tumbling velocity, the debris was assumed to transport to the strainer.

RAI-12: Describe the methodology and technical basis for the conclusion that 23% of the calcium silicate debris settles in the containment pool. State the size distribution of the calcium silicate that is assumed to settle in the containment pool.

RAI-12 RESPONSE: The basis for determining the total percentage of calcium silicate debris that settled out in the containment pool is documented in "St. Lucie 2 Nuclear Plant (PSL2) – Debris Transport" calculation. Based on the blast, washdown, and pool fill phases 13.19% of the calcium silicate debris is sequestered in inactive containment sump volumes.

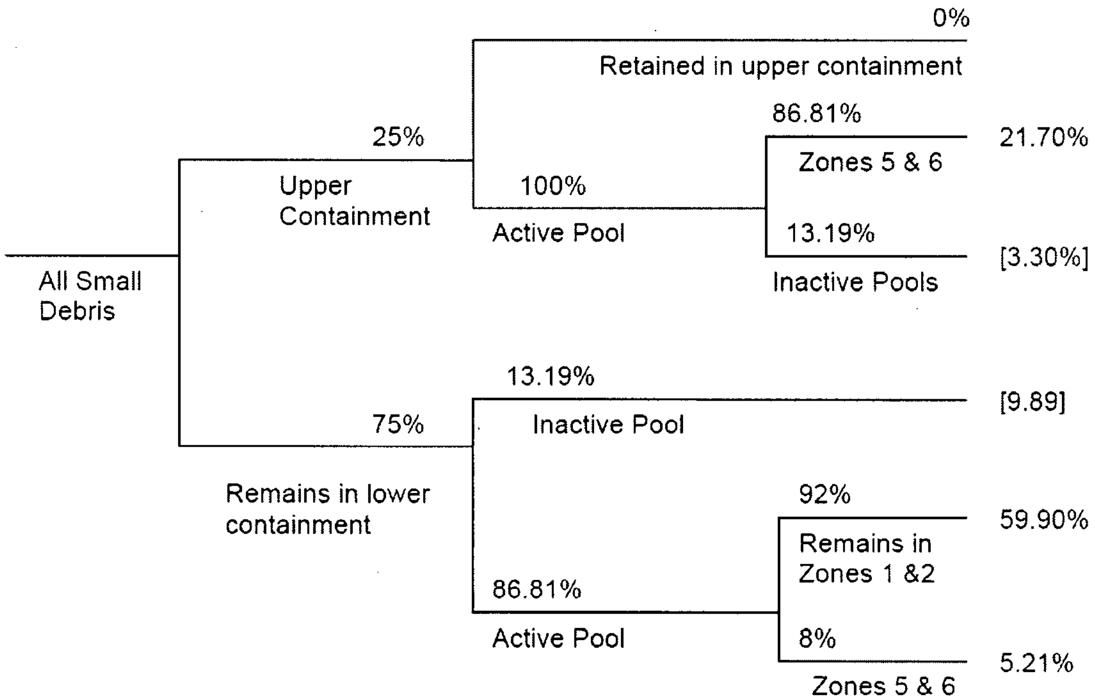


Figure 12-1: Small Debris Logic Tree for Blast, Wash Down, and Pool Fill

A CFD model was developed to determine the flow velocities throughout containment. The CFD model flow velocities are compared to the settling and incipient tumbling velocities for small debris to determine the portions of each zone that contribute to debris reaching the strainer. The debris that is subject to velocities lower than the settling and incipient tumbling velocities are not transported to the strainer and are assumed to settle in the containment pool (regardless of inactive or active containment pool). The settling and incipient tumbling velocities used in the analysis were obtained using NUREG/CR-6772 Sections 3.1.1, 3.2.1, and 3.3.1. The conclusion of the CFD analysis determined that 42.4% of the calcium silicate debris is transported to the vicinity of the strainer. 57.6% of the total debris quantity subjected to blast, pool fill, and recirculation effects was determined to settle either in inactive sump volumes or low velocity zones within the containment sump.

In the debris transport analysis, all calcium silicate is assumed to be "small" and fully transportable. The inactive sump settles 13.19% of the total calcium silicate debris; regardless of the fine and small size distribution of the calcium silicate.

The size distribution of the calcium silicate that is assumed to settle in the containment pool was not determined, but is also not significant. The exact dimensions for the size classifications of calcium silicate were not cited in the NEI 04/07. The debris transport calculation assumed that all calcium silicate is in the small category. The criterion for determining if it would transport was based only on whether the flow velocity in the pool was above the incipient tumbling velocity of calcium silicate as stated in NUREG/CR-6772.

RAI-13: Summarize the transport analysis methodology and results for the blowdown, washdown, and pool fill up transport process. At the onset of recirculation, where are the various types of debris assumed to be distributed, and how is this distribution modeled for the head loss tests that credit debris settling? What fractions of the debris are assumed to be trapped in inactive containment pools volumes?

RAI-13 RESPONSE: The transport analysis due to blowdown, washdown, and pool fill were calculated in the debris transport calculation. The methodology used in the analysis was developed using the guidance contained in NEI 04-07 volumes 1 and 2.

The following discussion is a summary of the transportation analysis methodology and results of the blowdown, washdown, and pool fill, as documented in the debris transport calculation. The St. Lucie Unit 2 debris transportation calculation developed the transportation logic for large and small debris associated with the St. Lucie Unit 2 break designated as "S1" worst case break location.

Small Debris Distribution

This discussion is a summary of the methodology applied to small debris. The lower containment was divided into seven (7) zones, as shown in Figure 13-1 below for illustration. Based on NEI 04-07 Volume 2, 25% of the small debris was transported vertically into upper containment and 75% remained in lower containment. For conservatism it was assumed all of the small debris that remained on the lower elevation was retained in zones 1 and 2 and subject to break flows during pool fill.

After initial blast the small debris was redistributed throughout containment due to pool fill effects and containment spray washdown effects. All small debris blown into the upper containment elevations were conservatively washed down to the lower elevation in zones 5 and 6 due to their close proximity to the containment sump. A small portion, 13.19% of the washdown debris was trapped in the inactive containment pool and not subject to transport to the strainer. Of the debris that remained in lower containment 13.19% was sequestered by the inactive pool volume, and the remaining 86.81% was available for further transport. Based on the approximate volume of water inside the secondary bioshield to the volume of water outside the secondary bioshield wall 92% of the non-sequestered small debris remained in zones 1 and 2. The remaining 8% transported through the secondary drain portals into zones 5 and 6. The distribution logic for small debris is presented below in Figure 13-1.

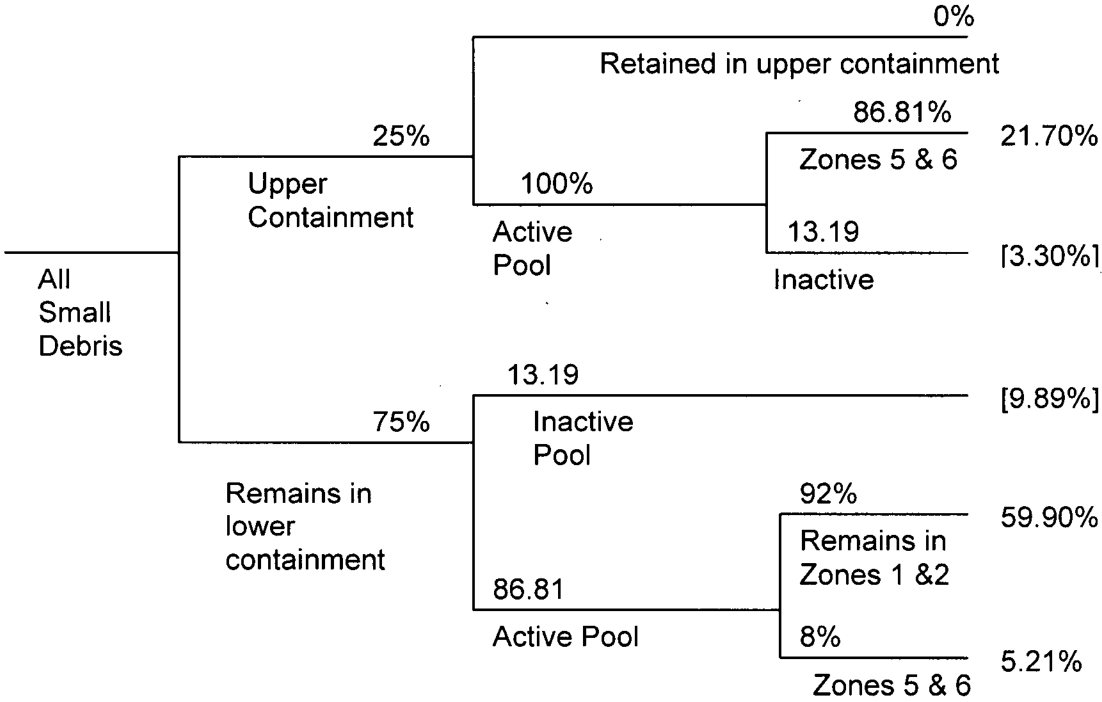


Figure 13-1: Distribution Logic for Small-Sized Debris that Originates in Proximity Zones 1 and 2 through Blowdown and Pool Fill Transport

Large Debris Distribution

Large debris was assumed to be largely influenced by gravity and remain in zones 1 and 2 post blowdown. The large debris was then distributed to various walls and wall openings based on the ratios of the total wall and opening lengths to individual wall and wall openings lengths. For conservatism large debris was not subjected to being trapped in the inactive containment pool. The ratios are further enhanced by accounting for the distance between the break and the object (wall or opening). A complete description of the debris distribution can be found in the debris generation calculation.

> "Initially large debris is assumed to be evenly spread over areas of zone 1 and 2. Using the S/L ratio of the openings compared to the total S/L[1] ratios, 15.35% of the large debris transports to the portal openings (1.42/9.25 = 0.1535). The pool fill hydraulics will push the remaining large debris against the walls in zones 1 and 2 (1-0.1535 = 0.8465), however 25% of the debris is assumed to shear off the wall (for conservatism) due to flow and transport along the walls to the drain portals. 90% of the debris that is transported to the portals is trapped by the installed trash racks, the remaining 10% will pass through. 10% of the large debris that becomes trapped on the trash racks will erode into fines and pass through the trash rack. The large debris that passes through the portals (as eroded fines) is assumed to be located outside the secondary bioshield wall in the trench at the designated opening. Additionally 10% of the large debris that remains trapped along the containment walls will be eroded to fines and available for further transport via the CFD analysis".

[1]"S" values are the measured width of the opening. "L" values are the distance from the break to the center of the opening.

The distribution logic for large debris is presented below in Figure 13-2.

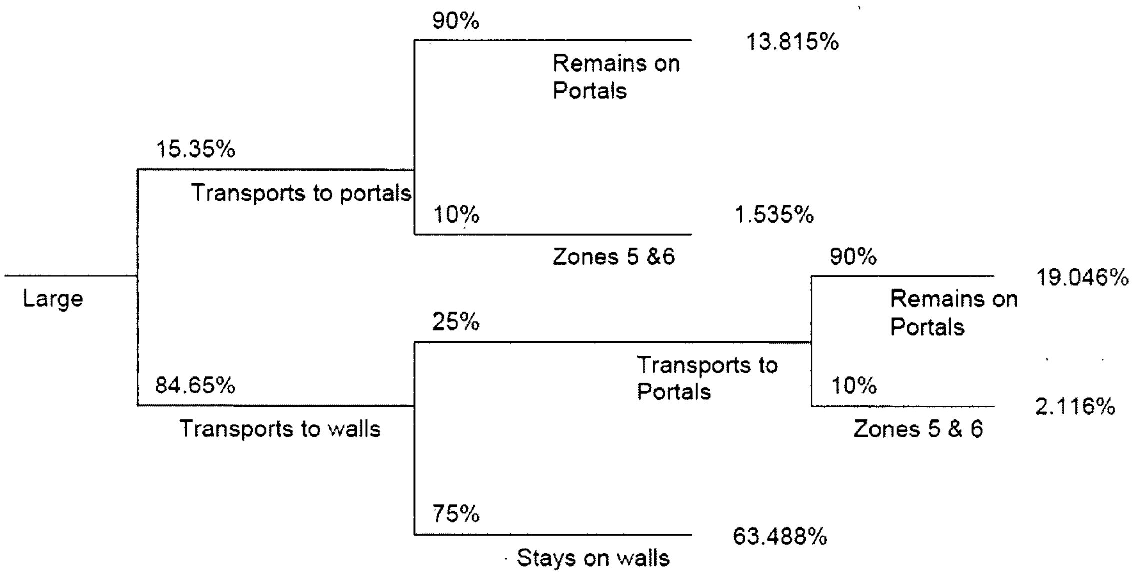


Figure 13-2: Distribution Logic for Large-Sized Debris

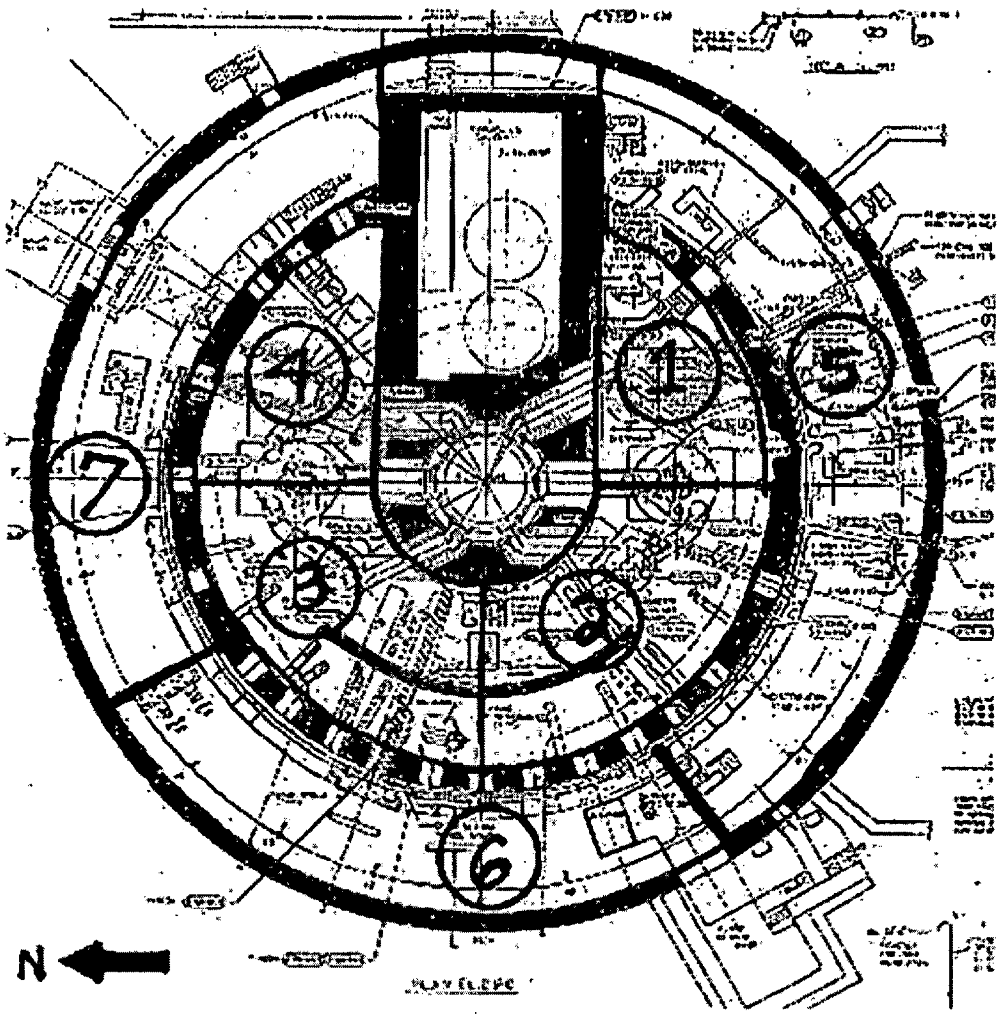


Figure 13-3: *Containment Zone Locations*

Inactive Pool

13.19% of the St. Lucie Unit 2 containment sump pool was calculated to be inactive. The inactive pool percentage was determined by calculating the volume inactive pools (11,360.8 ft^3) and dividing by the total containment pool volume (86,121.8 ft^3). For conservatism only small debris was subjected to inactive containment pool sequestering.

CFD Modeling

A CFD model was developed to determine the flow velocities throughout containment. The CFD model flow velocities are compared to the settling and incipient tumbling velocities for small debris to determine the portions of each zone that contribute to debris reaching the strainer. The settling and incipient tumbling velocities used in the analysis were obtained from NUREG/CR-6772. The conclusion of the CFD analysis determined the total quantity of individual debris types calculated to reach the vicinity of the strainer due to debris transport. The head loss testing conducted in the flume does not incorporate aspects of containment geometry and thus the zone distributions cannot be translated into distributions in the flume. The flume geometry is used to reproduce the weighted average approach flow velocities and velocity gradients through which debris travels near the strainer modules. The volume of material introduced in the flume is based on the volume of material predicted to move to the vicinity of the strainer array in the debris transport calculation.

RAI-14: Although the increased flow due to a low pressure safety injection (LPSI) pump appeared to have been partially accounted for in the head loss calculation, the additional flow from a containment spray system (CSS) or LPSI pump did not appear to have been incorporated into the transport analysis. Identify the containment pool height and sump flow rate assumed for the containment pool CFD calculation. If operator action during the high-stress period immediately following a loss-of-coolant accident (LOCA) is credited with terminating one CSS pump or terminating a LPSI pump that has failed to trip at switchover to sump recirculation, provide a technical basis for allowing this credit immediately after switchover to recirculation.

RAI-14 RESPONSE: The increased flow due to an operating LPSI pump has been accounted for in the head loss calculation, and the additional flow from a CSS or LPSI pump has been incorporated into the transport analysis.

For the debris transport calculation, it was assumed that the break flow falls to the pool water surface without contacting any equipment or structures. The break flow jet accelerates under the influence of gravity as it falls towards the water surface. This is a conservative method to model the break flow as it produces the greatest lateral outflow velocities along the floor. The upper boundary of the CFD model representing the water free surface was set at an elevation of 23.58 ft.

A single break corresponding to break S1 on the hot leg at the B steam generator was modeled in this simulation. Two scenarios of break flow, a high break flow rate of 4970 gpm and a low break flow rate of 1370 gpm, were considered. Spray flow of 3600 gpm was introduced into the containment building from spray headers located in the upper containment. The spray flow was assumed to be uniformly distributed on the surface of the water. The following table summarizes the break boundary conditions.

Break Boundary Conditions, Break S1

Scenario	Break Flow (GPM)	Spray Flow (GPM)	Break Diameter (in)	Break Velocity (FT/s)
1	4970	3600	9.50	22.49
2	1370	3600	4.99	22.46

The additional break flow for scenario 1 corresponds to the additional flow from an additional LPSI pump that is incorporated into the transport analysis. In the unlikely event of a LPSI pump failure to trip on recirculation actuation signal (RAS), the additional flow would be break flow.

Operator action is credited with stopping a second operating CSS pump because it is a requirement of St. Lucie Unit 2 Emergency Operating Procedures (EOPs) prior to the start of recirculation mode.

Operator action for stopping a failed to trip LPSI pump is part if the current St. Lucie Unit 2 licensing basis. According to the St. Lucie Unit 2 UFSAR, the failure of a LPSI pump to stop on RAS is listed as a failure mode considered for the St. Lucie Unit 2 design, the consequences of which are outlined therein. Credit for operator action to stop a LPSI pump is listed as the remedy for the failure and requirements for such action already exists in the emergency operating procedures and in the licensing and design bases.

It is generally accepted that most operator actions can be accomplished within a 30 minute period or less, especially if the action can be recognized in and accomplished from within the control room. Most Combustion Engineering (CE) plants are designed for automatic realignment of the ECCS system for the ECCS recirculation mode whereas most non-CE designed PWRs require and credit manual operator action for recognizing the need for and alignment of all recirculation components (i.e., sump, refueling water tank (RWT), and mini-flow recirculation valves – up to eight or more components) within a similar time period, irrespective if there is a single failure. These manual actions are required prior to RWT pump down and vortexing whereas the manual LPSI flow stoppage is required prior to debris head loss buildup, a significantly longer period of time.

St. Lucie Unit 2 EOPs call for ensuring RAS as a matter of specific procedural requirements and is consistent with CE EOP guidelines. A specific tabular checklist; Contingency Action 38A.1 is to MANUALLY ALIGN RAS COMPONENTS in accordance with Table 4 of EOPs, RAS Actuation. Table 4, step 3 requires the specific signoff for verification that both LPSI pumps trip or are manually stopped as in "ENSURE LPSI Pumps STOPPED".

The following design features support the current license basis that operator action can be credited to mitigate the failure to trip of a single LPSI pump upon RAS signal:

METHODS AVAILABLE TO MANUALLY STOP LPSI PUMP FLOW:

- Stop pump(s) from RTGB (main control board) control switch
- Stop pump(s) from Local PB (push button) station
- Stop pump(s) from 4160 V switchgear control switch
- Open 1E 4160 SWGR emergency bus feeder breaker/open emergency diesel generator (EDG) supply breaker on affected train bus
- Throttle closed LPSI header flow control valves to minimize LPSI flow until such time as pump can be stopped

CONTROL ROOM INDICATION OF OPERATING PUMP:

- Control switch lights
- Pump motor running current, on RTGB
- System header pressure
- System header flow

CONTROL ROOM INDICATION OF POTENTIAL PUMP CAVITATION:

- Erratic pump motor running current, on RTGB
- Erratic system header pressure
- Erratic system header flow

CONTROL ROOM INDICATION OF POTENTIAL LOSS OF 1E 125 DC CONTROL POWER:

- Loss of all control switch indicating lights for the affected LPSI pump motor.

CONTROL ROOM INDICATION OF RAS ACTUATION

- Control room indication

It can be concluded that the existing design and licensing basis and procedural requirements which credit operator action to stop flow from a single LPSI pump after failure to trip on RAS continue to apply for the new GSI-191 ECCS/CS strainer design for St. Lucie Unit 2.

RAI-15: In the upstream analysis, the supplemental response states that chokepoints in the ECCS trench are not an issue because large pieces of debris will not enter this trench due to the presence of trash racks around the bioshield wall. However, the supplemental response did not address the potential for large debris to be blown into upper containment and then washed down by containment sprays outside of the bioshield wall downstream of the trash racks. Provide a basis to justify that blockage in the ECCS trench will not occur in light of the phenomenon discussed above.

RAI-15 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 SBS wall through the floor at elevation 62 and outside the SBS wall. The limiting St. Lucie Unit 2 breaks are within the SBS wall around the RCS loop level.

No significant pathway was found to exist through the SBS wall at the lower wall drain windows which are blocked with trash racks.

On elevation 62' the floor area is primarily concrete above the lower area which is encompassed by the secondary bioshield wall. Containment spray water on the concrete floor will primarily flow through floor drains with grilles to capture debris. Also, on elevation 62' the floor area is grating above the lower area outside the secondary bioshield wall. There is an opening between the grating and the steel containment vessel of approximately 4-1/2". However, there is a 4" kick plate on the outside circumference of the grating. The grating will filter debris contained in containment spray water passing through the grating and the kick plate will prevent debris from passing through the gap between the grating and the steel containment vessel. Similarly, grating at the 45' elevation would act as a filter for debris that passed through the upper grating.

A walk down of the upper elevations of containment was performed to confirm a lack of potential chokepoints at these elevations. Much of the floor at the elevations above the ground floor consists of grating and openings, and the remainder is a flat concrete slab. The transition from concrete to grating is typically a smooth transition so that water would not be retained. There are also openings for stairs between each elevation, as well as openings for pipes and other components. Since only small debris is expected to transport to higher elevations, the grates are not expected to retain any significant quantities of debris or water.

Therefore, the primary flow path for recirculation flow brings water from within the inner annulus (18' elevation) to the sump via the ECCS trench. It was found during the walkdown that some areas of the trench contained piping, pipe supports, and pipe restraints (see figure 15-2). The trench was found to be relatively open on the ends furthest from the sump, and became gradually more congested nearer the sump.

Heavy trash racks screen the 20 "window" entrances to the trench from within the SBS. Any large debris generated by a large break LOCA (LBLOCA) would occur inside the SBS. Therefore, significant quantities of large debris would not be expected to enter the trench. Furthermore, the direct path from the 18' elevation to the sump via a portal directly into the sump offers an alternate path to the trenches.

Three stairways through the SBS wall for personnel access in addition to the 20 "windows" will also form flow paths during recirculation. These, too, are protected by large steel trash racks that prevent passage of large debris into the trench. These are equivalent to the trash racks at the 20 trench portals in function.

If you assume that significant large debris is able to make its way vertically over 40 feet against the forces of gravity and falling containment spray flow and through the aforementioned tortuous path to the ECCS trenches outside of the SBS wall, the following design features preclude total flow blockage of both ECCS trenches:

1. The ECCS trenches are located around 270 circumferential degrees of containment just outside of the SBS wall (see figure 15-1 below). Much of the trench is covered by grating or floor which would restrict the intrusion of large debris. Should a portion of trench be partially or totally blocked at some point, numerous alternative flow paths to the ECCS strainers remain.

2. The ECCS trench approaches the ECCS sump strainer from both the east and west. Thus, in the unlikely event that one trench was to become partially or completely blocked, flow from the trench in the opposite direction still reaches the strainers.

3. The floor outside the SBS wall and around the sump pit and ECCS trench is at the 23' elevation. Minimum post LOCA containment pool level is greater than 23.00 ft. Therefore, separate flow paths exist from anywhere at the 23 ft level to the ECCS trench or sump itself. If the ECCS trench is partially or completely blocked, over the top flow is still possible.

4. Since the ECCS trenches contain some piping supports and equipment, it is very improbable that debris of such size and exact geometry could pass into and completely or significantly block a trench due to interfering piping or equipment (see figure 15-2).

5. Portions of the ECCS trench nearest the ECCS strainers are covered with grating.

6. Flow may also reach the sump from the 23' elevation by entering the top of the sump through grating directly.

7. Finally, the smallest cross section of the ECCS trench is 5 ft. wide by 7 ft tall. Such a cross section would require quite a large perfectly placed section of debris to disrupt flow. The trench cross section becomes deeper as the strainers are approached (see figure 15-2 for a photograph of the trench).

Note that the debris transport calculation conservatively (for the purposes of that report) assumed the trench to be open to maximize the quantity of debris that reaches the sump screen. In summary, primarily because of the trash racks preventing large debris from entering the trench, a chokepoint is not expected to occur in the recirculation trench approaching the sump.

Therefore the ECCS recirculation trenches do not create a chokepoint at St. Lucie Unit 2.

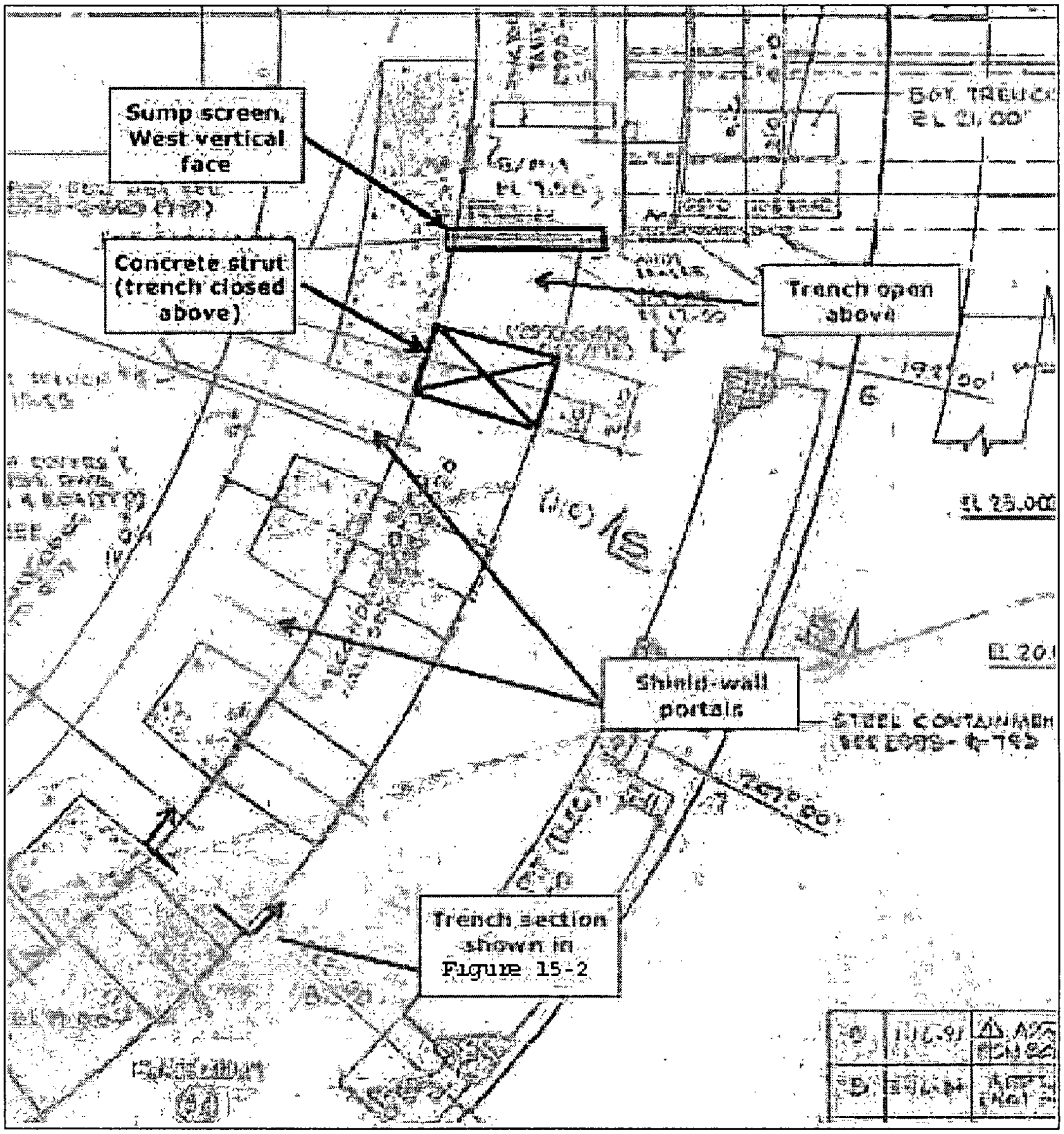

Sump screen, West vertical face
Concrete strut (trench closed above)
Trench open above
Shield-wall portals
Trench section shown in Figure 15-2

Figure 15-1

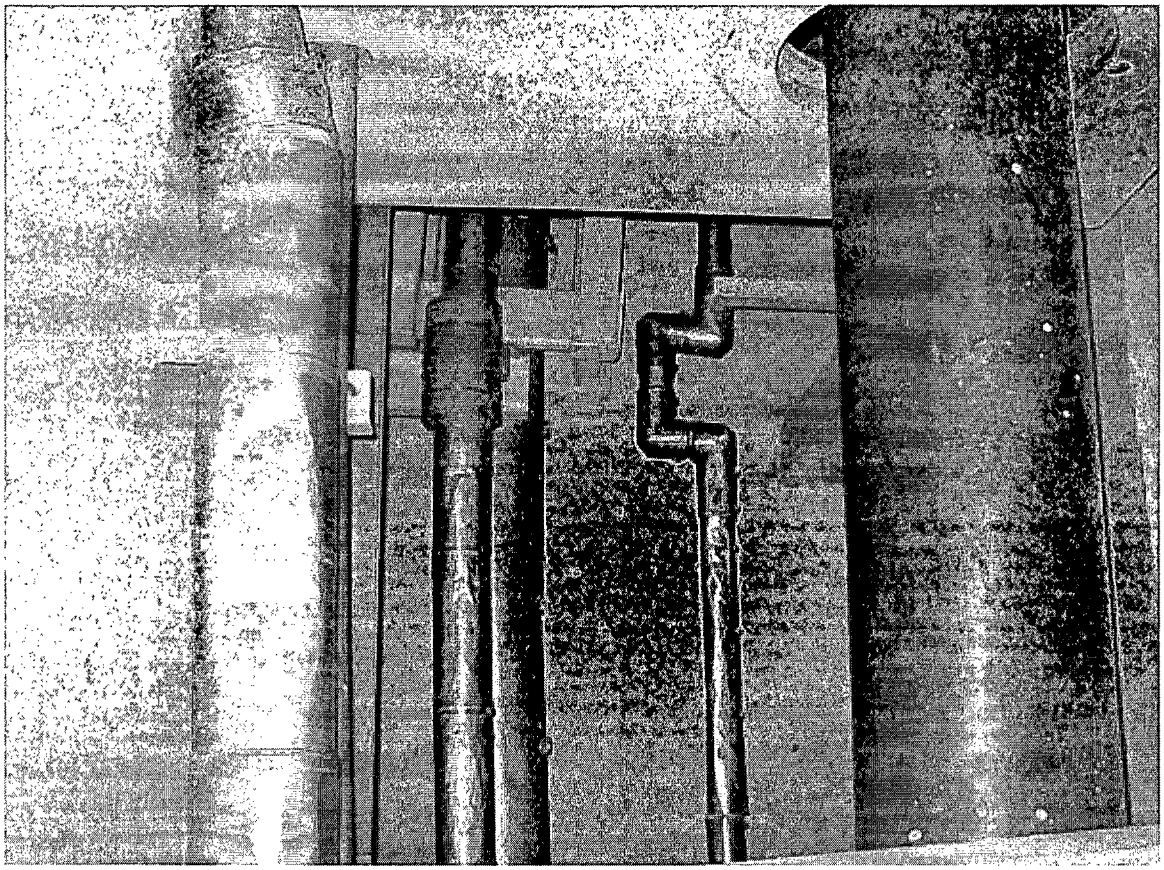


Figure 15-2 ECCS TRENCH

RAI-16: Your submittal indicates that the trisodium phosphate (TSP) is stored in sixteen open baskets in the vicinity of the containment sump. Discuss the distance from the various TSP baskets to the sump strainer relative to the distance in the Alden flume from the chemical precipitate addition point to the test strainer. Given the more rapid settling characteristics for calcium phosphate precipitate, justify why the transport of calcium phosphate in the test flume is conservative relative to the plant. The staff notes that there is uncertainty concerning where calcium phosphate would form as both calcium silicate insulation fines and TSP will dissolve in the post-LOCA pool.

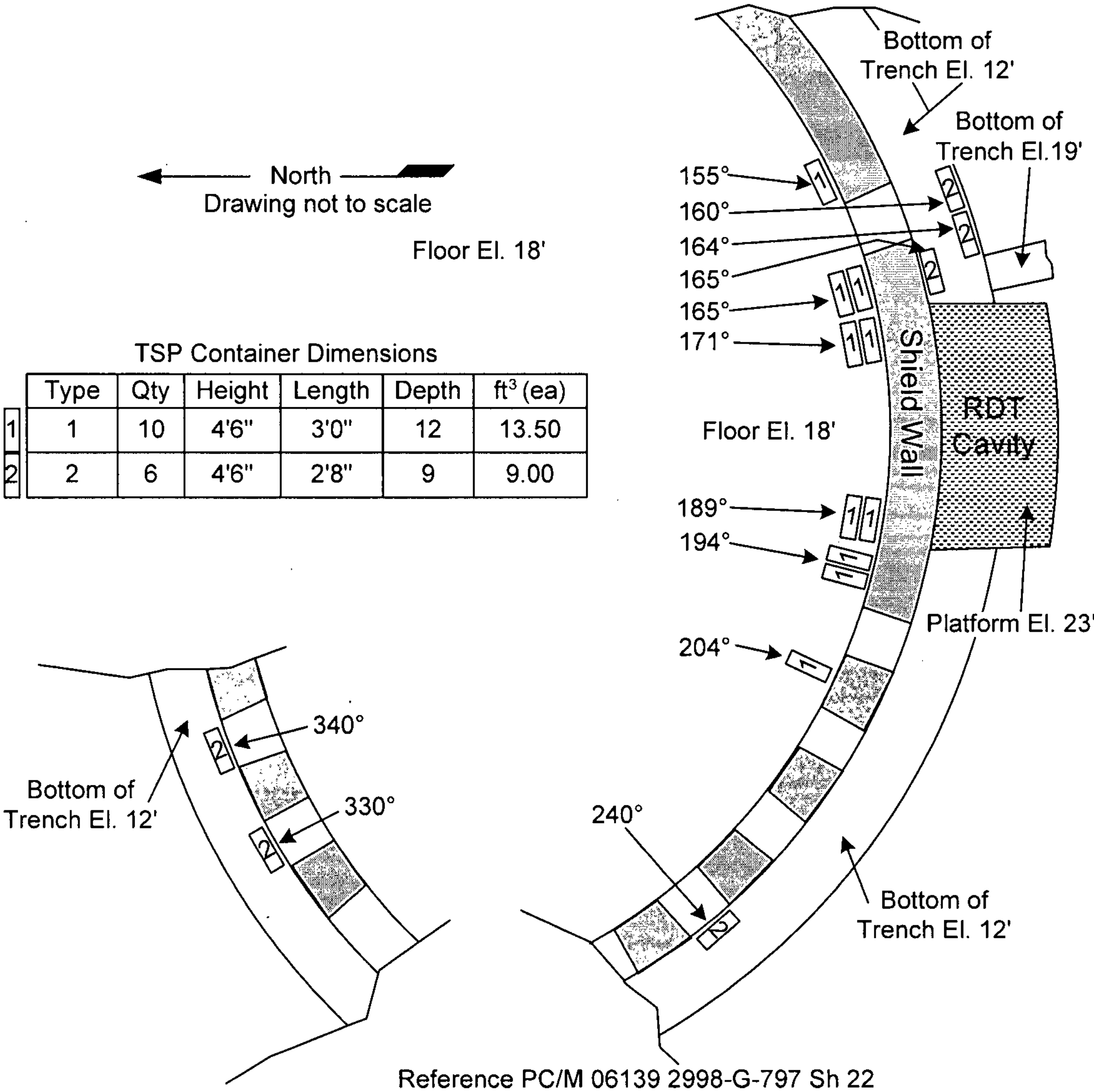
RAI-16 RESPONSE: The St. Lucie Unit 2 TSP containers are of two sizes, type I and type 2, and are arranged both within and outside of SBS wall (see Figure 16-1). Ten 13.5 cubic feet containers are within the SBS wall and six 9 cubic foot containers are outside the wall and located inside the ECCS trench at various distances from the ECCS/CSS strainers. The six smaller containers were relocated from the sump pit (reactor drain tank (RDT) cavity) to make room for the new strainers. Thus, the majority of the TSP volume is on the opposite side of the SBS wall from the ECCS/CSS strainers and requires significant approach and flow direction changes to reach the strainers.

It has been estimated that the weighted average (based on basket volume) of the distances from the TSP baskets to the ECCS/CSS strainers is approximately 29 ft. This is comparable with the test flume especially when you consider the plant distances include directional changes. Location of the baskets, however, is of minimal importance for calcium phosphate formation since the TSP dissolves early in the event and is distributed throughout containment by CSS. If calcium silicate insulation fines are dissolved, then they too will be distributed throughout containment.

The UFSAR Section 6.5.2.3.2 states that approximately one-third of the TSP is dissolved within 20 minutes (prior to recirculation) and all of the TSP is dissolved within three hours. The benchmark gives a TSP dissolution of 33.1% within 20 minutes and 100% within three hours.

An analysis performed for FPL shows that the Type 2 containers could be moved from the sump to the new locations without invalidating the previously identified statement from the UFSAR.

Calcium phosphate ($Ca_3(PO_4)_2$) was introduced into the Alden test flume over a two day span in small batches of 28 gallons and 17 gallons. The first three batches of $Ca_3(PO_4)_2$ were batched into the test flume at a volume of 28 gallons. The remaining batches to complete all $Ca_3(PO_4)_2$ introductions were batched into the test flume at a volume of 17 gallons. The purpose for these batch volumes was to prevent the flume from becoming overly concentrated with chemical debris, thus causing the $Ca_3(PO_4)_2$ to settle more quickly on the flume floor.



TSP Container Dimensions

	Type	Qty	Height	Length	Depth	ft^3 (ea)
1	1	10	4'6"	3'0"	12	13.50
2	2	6	4'6"	2'8"	9	9.00

Figure 16-1 Note that a portal at azimuth 180 has been omitted

The amount of LOCA generated calcium silicate in the St. Lucie Unit 2 containment is relatively small and generally confined to pipe support shields. This volume conservatively includes insulation affected by the break, insulation in the submergence zone, and insulation outside the SBS wall on a vertical support that could be affected by containment spray. The scaled amount tested in the flume included significant margin based on the debris generation calculation and the transport calculation. The limiting LOCA break and this material reside within the SBS wall. Thus transport is required from the break area through the SBS wall to the strainers.

The test apparatus consisted of a steel flume measuring 10' wide, 5' deep (with a 6' deep pit) and 45' long (see figure 16-2). Inside of the steel flume, plywood was used to contour the flume walls to simulate the containment approach velocities. The upstream most portion of the flume was used to introduce the flow into the flume resulting in a 35.46' test section. The introduction of chemicals and debris is in accordance with the agreed upon protocols by the NRC, at the drop zone. If the calcium phosphate partially settles in the flume, then it will settle in the containment as well. Per the agreed protocol, the chemicals were not introduced right on top of the strainer, so as not to disturb the fiber bed by dumping material in close proximity to the screen.

Calcium phosphate was introduced to the test flume both as the full mass of calcium silicate insulation material and as the full mass of calcium phosphate predicted to be reacted. Thus the debris burden due to calcium is at least partially duplicated and redundant. This is because calcium silicate would be expected to transform/react with TSP consuming part of the calcium silicate material in the post LOCA environment.

Therefore, the transport of calcium phosphate in the test flume for St. Lucie Unit 2 is conservative relative to the plant because:

- The Alden test flume length is prototypical of the relative plant distances from TSP basket to strainer.
- TSP basket location is of lesser importance because a large amount of TSP is dissolved prior to and early in ECCS/CSS recirculation which distributes the material throughout containment via containment spray.
- Calcium phosphate was introduced gradually to the test flume as batched liquid solution which minimizes settling in the test flume prior to reaching the strainer test module.
- The test flume was a direct/straight approach to the test strainer whereas the actual plant involves directional and elevation changes prior to reaching the strainer.
- The test debris burden due to calcium was at least partially duplicated and redundant since full measures of both calcium silicate and calcium phosphate were introduced separately into the test flume.
- Although relatively small, there remains significant margin in both the volume of calcium silicate generated and tested.

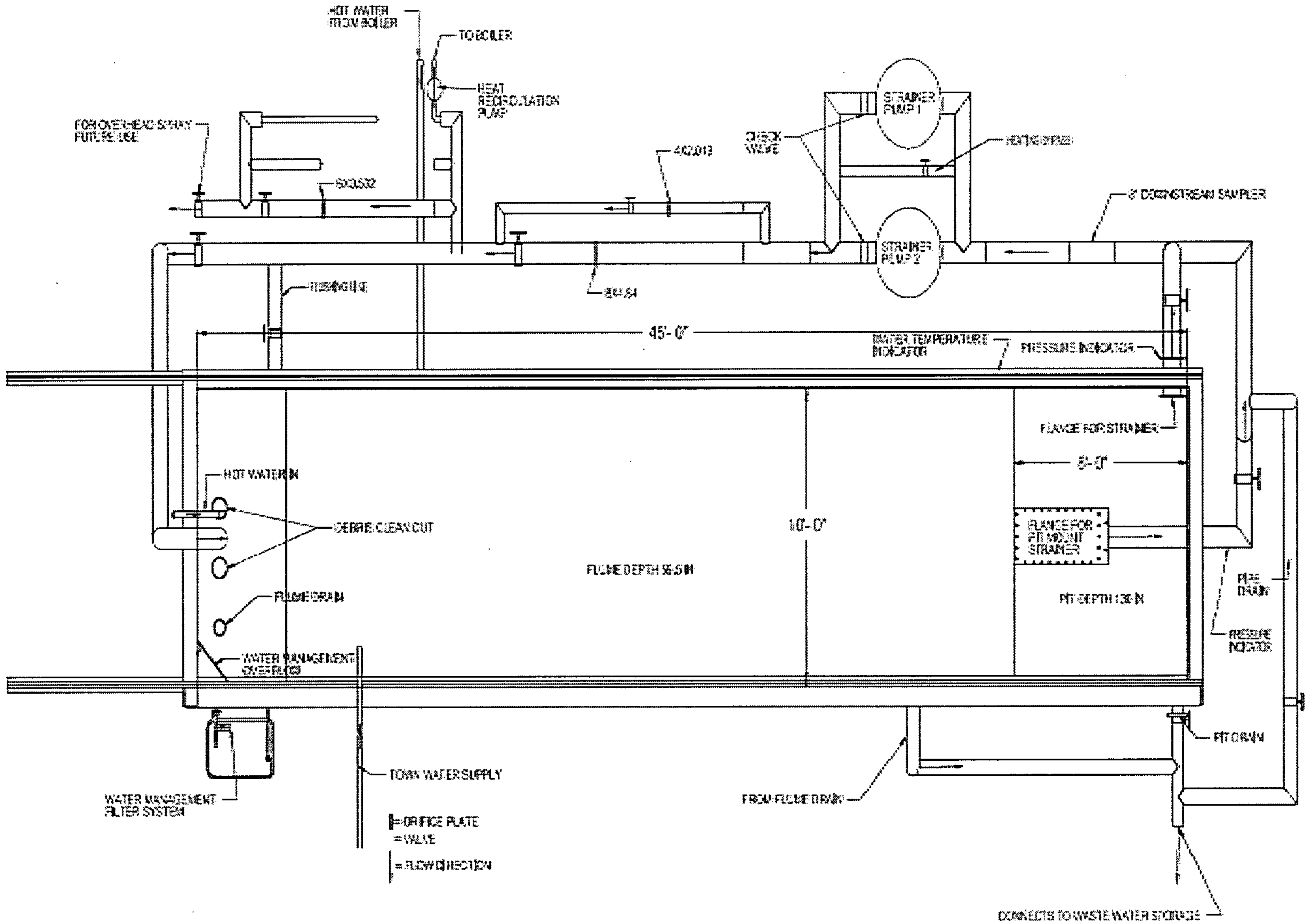

HOT WATER FROM BOILER
TO BOILER
HEAT RECIRCULATION PUMP
FOR OVERHEAD SPRAY FUTURE USE
STRAINER PUMP 1
STRAINER PUMP 2
CHECK VALVE
FLUSHING LINE
45'- 0"
WATER TEMPERATURE INDICATOR
PRESSURE INDICATOR
FLANGE FOR STRAINER
8'- 0"
HOT WATER IN
DEBRIS CLEAN OUT
10'- 0"
FLANGE FOR PIT MOUNT STRAINER
FLUME DEPTH 56.5 IN
PIT DEPTH 130 IN
FLUME DRAIN
PIPE DRAIN
PRESSURE INDICATOR
WATER MANAGEMENT OVER FLOW
PIT DRAIN
TOWN WATER SUPPLY
WATER MANAGEMENT FILTER SYSTEM
FROM FLUME DRAIN
= ORIFICE PLATE
= VALVE
= FLOW DIRECTION
CONNECTS TO WASTE WATER STORAGE

Figure 16-2

RAI-17: Table 3.f-1 on page 18 of the supplemental response provided CSHL values for both the strainer modules and core tubes, as well as components between the strainers and the ECCS suctions. Describe the methodology used to calculate the CSHL values for the non-strainer module and core tube components.

RAI-17 RESPONSE: PCI utilizes conventional hydraulic calculation applications and methodology to determine the clean strainer head loss (CSHL) of the Sure-Flow® suction strainer connecting piping and fittings, or collection plenum. Each of the fluid flow path components (i.e., pipe, fittings, plenum, etc.) from the Sure-Flow® suction strainer discharge to the final component discharge into the licensee sump or pipe is individually analyzed in order to determine the Total CSHL. A level of uncertainty is applied to the individual head loss components as appropriate. The individual head loss components are then added to the Sure-Flow® suction strainer CSHL to obtain the licensee's total CSHL. Recognized hydraulic calculation references such as Crane Technical Paper No 410, *Flow of Fluids Through Valves, Fittings, and Pipe,* I.E. Idelchik's *Handbook of Hydraulic Resistance,* and *Marks' Standard Handbook for Mechanical Engineers*, among others are utilized as applicable and appropriate. PCI does not employ computer based specific software such as Engineered Software's *Pipe-Flo* or other such software to calculate the licensee's total CSHL.

RAI-18: The supplemental response stated that the total strainer head loss can be calculated by adding the CSHL and debris head loss, then temperature correcting the sum of the two. Separate methodologies should be used for the temperature correction for each of these two distinct head loss components because debris bed head loss is generally laminar while CSHL is always turbulent. Describe the methodology used to arrive at the total head loss for the system at elevated temperatures. If the clean strainer and debris head loss corrections were calculated separately, describe the method for each. Provide the assumptions and bases used for this evaluation.

RAI-18 RESPONSE: PCI calculates the CSHL and total strainer head loss (TSHL) as follows.

The CSHL normally consists of two (2) separate parts: (1) the Sure-Flow® suction strainer head loss, and (2) the fluid flow path components (i.e., pipe, fittings, plenum, etc.) from the Sure-Flow® suction strainer discharge to the final component discharge into the licensee sump or pipe. Once the CSHL of the Sure-Flow® suction strainer arrangement is calculated, it is added to the debris laden head loss based on licensee specific testing performed at the Alden Research Laboratory (ARL) to establish the TSHL for the licensee's plant. Each portion of the TSHL, that is, the Sure-Flow® suction strainer head loss, the fluid flow path components, and the ARL test debris laden head loss are temperature corrected as applicable and appropriate to the licensee's design basis temperature.

The Sure-Flow® suction strainer head loss (that is the CSHL for the SFS module) is determined by application of the PCI "Regression Formula" that is described in the proprietary PCI 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*. 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 PCI "Regression Formula" incorporates the ability to perform temperature corrections to the licensee's design basis temperature through the associated water kinematic viscosity values. The remaining portions of the Sure-Flow® suction strainer other than the core tube which is addressed by the "Regression Formula" are analyzed by conventional hydraulic calculation applications and methodology to determine their portion of the Sure-Flow® suction strainer CSHL. A 6% level of uncertainty is applied to the Sure-Flow® suction strainer CSHL.

PCI utilizes conventional hydraulic calculation applications and methodology to determine the CSHL of the Sure-Flow® suction strainer connecting piping and fittings, or collection plenum. Each of the fluid flow path components (i.e., pipe, fittings, plenum, etc.) from the Sure-Flow® suction strainer discharge to the final component discharge into the licensee sump or pipe is individually analyzed in order to determine the total CSHL. A 10% level of uncertainty is applied to the individual head loss components as appropriate. The individual head loss components are then added to the Sure-Flow® suction strainer CSHL to obtain the licensee's total CSHL. Recognized hydraulic calculation references such as Crane Technical Paper No 410, *Flow of Fluids Through Valves, Fittings, and Pipe,* I.E. Idelchik's *Handbook of Hydraulic Resistance, Marks' Standard Handbook for Mechanical Engineers*, and the *Moody Diagram* among others are utilized as applicable and appropriate. PCI does not employ computer based specific software such as Engineered Software's *Pipe-Flo* or other such software to calculate the licensee's total CSHL.

The debris laden head loss for licensees utilizing the Sure-Flow® suction strainer is based on licensee plant specific testing at ARL. The licensee plant specific CSHL for their Sure-Flow® suction strainer is first established based on testing at ARL. This is done in order to establish the "base" CSHL of the actual plant specific strainer module. The licensee plant specific design basis debris allocation (i.e., fibrous, particulate, miscellaneous, and chemical precipitate debris) is then added to the ARL test flume. The ARL test flume configuration utilized is licensee plant specific and is the result of a conservative double-weighted CFD model that is representative of the post LOCA fluid conditions within the containment. The CFD model provides a conservative representation of the fluid flow velocities of the licensee's plant. The ARL test CSHL is subtracted from the debris laden head loss determined at ARL for the licensee plant specific Design Basis debris allocation in order to determine the debris only head loss portion for the licensee's plant.

The CSHL previously calculated for the licensee specific plant is then added to the licensee specific plant ARL debris laden head loss to determine the total licensee plant specific debris laden head loss for the licensee's plant specific strainer configuration. The strainer module is temperature corrected through the use of the PCI "Regression Formula." The licensee strainer configuration connecting piping and fittings, or collection plenum CSHL is determined by conventional hydraulic calculation applications and methodology, including use of the Moody Diagram as appropriate. The licensee plant specific debris laden only head loss portion is temperature corrected utilizing water dynamic (absolute) viscosity values. PCI can scale the debris laden only head loss portion since all licensee testing of their plant specific Sure-Flow® suction strainer in conjunction with their plant specific Design Basis debris allocation has shown that the formation of vortices or boreholes have not been observed during actual testing at ARL.

The following table summarizes the calculation and temperature correction methodology utilized by PCI to calculate the CSHL and TSHL.

Sure-Flow® suction strainer Head Loss Component	Head Loss Determination Methodology	Temperature Correction Methodology	Comment
SFS Module CSHL	PCI "Regression Formula"	Kinematic viscosity used within formula for temperature correction	Establishes CSHL of Sure-Flow® suction strainer modules
SFS "Non-Module" Connecting Piping and Fittings, or Collection Plenum	Conventional hydraulic calculation applications and methodology	Moody Diagram as appropriate	Establishes CSHL of Sure-Flow® suction strainer Non-Module piping & fittings, or collection plenum
ARL SFS Module CSHL	Actual Sure-Flow® suction strainer module test results	Kinematic viscosity of water used for correction from test to Design Basis temperature	Establishes CSHL of Sure-Flow® suction strainer modules based on actual testing
ARL SFS Debris	Actual Sure-Flow®	Dynamic (absolute)	Establishes TSHL of

Laden Head Loss	suction strainer module debris laden test results	viscosity of water used for correction from test to Design Basis temperature	Sure-Flow® suction strainer modules based on actual testing

The following summarizes how the various strainer head loss components discussed in the table are utilized to determine the licensee's Sure-Flow® suction strainer arrangement total strainer head loss:

  SFS module CSHL
\+ SFS "non-module" connecting piping and fittings, or collection plenum
\- ARL SFS module CSHL
\+ ARL SFS debris laden head loss
= Sure-Flow® suction strainer arrangement total strainer head loss

RAI-19: The supplemental response stated that the B train CSHL is higher than the A train CSHL and is, therefore, bounding. However, the limiting calculations are presented using the A train CSHL. It is, therefore, unclear when the A and B train CSHL results should be applied. Provide information that justifies the use of the lower A train CSHL in some calculations.

RAI-19 RESPONSE : The overall ECCS/CSS suction head losses consist of a) strainer screens, core tubes, plenums, entrance and exit losses, plus b) the original system piping losses from the sump to the ECCS and CSS pumps.

The B train data is for the strainer only. The CSHL calculation by the St. Lucie Unit 2 strainer vendor included head losses for strainer screens, core tubes, plenums and associated entrance and exit losses.

Table 3.f-1, *Calculated Clean Strainer Head Losses @ 210° F, of the FPL supplemental response, which presented the A and B train strainer stack losses, does not include losses in original ECCS/CSS piping which follow downstream of the strainer plenum and continue to pump suctions. B train strainer stack CSHL is slightly higher and bounding for the strainer and plenum only as shown in Table 3.f-1. The differential in calculated CSHL between the two different strainer sides at balanced full flow is only 0.24 ft.

See the note following Table 3.f-1 *Calculated Clean Strainer Head Losses @ 210° F: "* Note, does not include piping and other head losses from the entrance of the piping to the suction of the ECCS/CSS pumps".

The original NPSH calculations for the existing ECCS/CS suction piping had determined, based on piping and equipment take offs, that train A HPSI and CSS suction piping is most resistive and has higher more limiting head losses for the pump suction lines.

To determine the overall (strainers and original piping) head loss from strainer to ECCS/CSS pumps for the unbalanced flow cases (CSS pump stoppage and LPSI failure to trip), the A train original piping head losses are more severe than the lesser strainer loss differential. That is, the difference in the downstream suction piping head losses is greater than the difference in the strainer head losses. This is because all of the unbalanced flow passes through the piping, whereas, there is partial cross flow within the shared strainer plenum utilizing flow from both trains of strainer stacks. Therefore, for conservatism, a HPSI pump, the operating CS pump, and failed to trip LPSI pumps are all assumed to be flowing through the same A train suction piping for the overall head loss determination. The CSHL calculation includes 10 % margin to accommodate any disparities.

Accordingly, the limiting case was presented for train A which is input to the overall head loss, including strainer and original piping, when applied to the NPSH calculations for the unbalanced flow cases.

<u>RAI-20:</u> The supplemental response stated that the debris bed portion of head loss for the single worst case failure of a LPSI pump to trip is 0.416 ft. This is lower than debris bed head losses at similar temperatures and lower flow rates. It is unclear how this debris bed head loss was determined. Provide the raw test results for debris bed head loss and describe the methodology used to extrapolate these results to conditions other than the test condition. Provide the relevant test conditions. Provide the assumptions and bases for the methodology used. For each extrapolated condition, provide the debris bed head loss and clean strainer head loss separately.

<u>RAI-20 RESPONSE:</u> As stated in the supplemental response, an additional calculation for a LBLOCA was completed. This calculation assumed a single failure of a LPSI pump to trip at the initiation of RAS. The Operator would take action to trip this pump manually during procedural verification of RAS actions. However, although this flow condition would be temporary, it would be the highest possible flow condition, 8470 gpm from the containment sump (7785 + 685). It is noted that the calculation assumes, under these temporary conditions immediately following RAS, that the strainers would remain clean with little or no debris head loss. However, for conservatism, full debris head loss without chemical precipitate based on flume test measured head loss values approximately two hours into testing were considered.

Flow cases were considered in the NPSH calculations which bound the instance when a LPSI pump fails to stop upon initiation of recirculation. One case considers the LPSI pump still operating and drawing suction from the suction line opposite from the suction line the operating CSS pump is taking suction from. Another case considers that both the LPSI pump which remains operating and the operating CSS pump are taking suction from the same suction line. In both instances, even though the period of time for which the LPSI pump operates will be small, and significant debris head loss would not yet have been developed on the strainers, conservatively a small amount of debris head loss was considered for these two cases. From the test report, a conservative head loss value is 0.915 ft as shown in Table 20-1. This number was measured at 108.1 °F, temperature correcting this loss to 210 °F yields a head loss of 0.416 ft. (0.915 * 5.96E-6 / 13.10E-6).

Table 20-1 RAW TEST DATA Debris Loaded Head Loss Results

TEST	Strainer Flow Rate (gpm)	Debris Loaded Head Loss (ft of water)	Average Temperature (°F)
Design Basis High Flow (pre chemical addition)	873.7	0.915	108.1

0.416 ft is less than the full debris laden head loss of 0.892 ft since chemical precipitate is not included.

For comparison, the CSHL is presented in Table 20-2 for the higher LPSI failed to trip flow rates.

Table 20-2 RAW TEST DATA Test 1: Clean Strainer Head Loss

Target Flow Rate (gpm)	Average Measured Flow Rate (gpm)	Stabilized Strainer Differential Pressure (ft. of H_2O)	Average Water Temperature (°F)
864	866.7	0.027	113.4
1000	1015.1	0.028	113.6

The clean head losses are so low as to not require scaling.

RAI 21: Verify that the vortex testing was conducted at prototypical or conservative flow rates and physical conditions (e.g., test flume arrangement versus plant sump geometry).

RAI 21 RESPONSE: St. Lucie Unit 2 strainer testing was conducted in accordance with the AREVA St. Lucie Unit 2 Strainer Test Plan. Per the test plan the strainer was monitored for vortex formation. There was no evidence of vortex formation on a debris laden strainer as the water level dropped to 2-3 inches below the top of the perforated plate as documented in the strainer test report. The St. Lucie Unit 2 strainer is installed within the containment sump (lower than the containment 23 ft. floor elevation) creating a sump "pit" that surrounds the strainer. Strainer testing was also completed utilizing a sump "pit" configuration. The maximum submergence of the test strainer was less than the minimum plant strainer submergence; therefore, the test conditions represented the bounding condition for vortex formation and observations.

FPL calculations assume that "A scaled strainer, which is designed to maintain the same approach velocity as the full scale production strainer, can accurately simulate the performance of the full scale production strainer so long as the same scaling factor is used for strainer area, water flow rate, and debris quantities". The AREVA test plan ensures the test conditions meet these requirements by requiring the use of the PCI calculated scaling factor to determine flow rates, and debris loads. AREVA ensures the testing values are conservative by requiring the flow be within -0% and +5% of the PCI calculated flow rate. This ensures the minimum flow velocities are maintained and will not be affected by flow fluctuation during the test. The test flume wall configuration is designed to simulate plant strainer approach stream lines and velocities as calculated in the AREVA debris transport calculation.

RAI-22a: Provide documentation of the head loss testing methodology, including; Debris introduction sequence (debris type and size distribution) included time between additions.

RAI-22a RESPONSE: The debris loaded strainer head loss test methodology and raw data is documented in the St. Lucie Unit 2 Strainer Test Plan and the analyzed data is presented in the St. Lucie Unit 2 Strainer Test Report. For the size distribution of fibrous debris see response to RAI 22e. For the size distribution of particulate debris see response to RAI 22f. The test report summarizes the debris introduction and is presented below.

All batches except for batch 1 were introduced at the drop zone, upstream of the prototype strainer. Batch 1 was introduced along the length of the flume prior to the start of the recirculation pump. Batch 1 was used to simulate latent debris which may be blown closer to the strainer at the start of a LOCA. The order for debris introduction, along with the measured amounts, was as follows:

Batch 1: ~25% of PSL2 latent fibrous debris (Nukon fine fiber, .33 lbm)

Fine Particulate Debris

Batch 2: 100% PSL2 Cal-Sil (15.50 lbm)

Batch 3: 100% of PSL2 Walnut Shell particulate debris (108.75 lbm).

Batch 4: 100% of PSL2 Tin particulate debris (157.5 lbm)

Batch 5: 100% of PSL2 Dirt & Dust (7.25 lbm)

Fine Fibrous Debris

Batch 6: 100% of PSL2 fine Nukon fibers and the remainder (75%) of the Latent fibrous debris (~68.3 lbm)

Small Fibrous Debris

Batch 7: 100% of PSL2 small Nukon fibers. (68.40 lbm)

Chemical Precipitate Debris

Aluminum Oxyhydroxide (ALOOH) was introduced into the test flume over a two day span in small batches of 24 gallons and 14.5 gallons. The first three batches of ALOOH were batched into the test flume at a volume of 24 gallons. The remaining batches to complete all ALOOH introductions were batched into the test flume at a volume of 14.5 gallons. The purpose for these batch volumes was to prevent the flume from becoming overly concentrated with chemical debris, thus causing the ALOOH to settle quicker on the flume floor.

Calcium Phosphate ($Ca_3(PO_4)_2$) was introduced into the test flume over a two day span in small batches of 28 gallons and 17 gallons. The first three batches of $Ca_3(PO_4)_2$ were batched into the test flume at a volume of 28 gallons. The remaining batches to complete all $Ca_3(PO_4)_2$ introductions were batched into the test flume at a volume of 17 gallons. The purpose for these batch volumes was to prevent the flume from becoming overly concentrated with chemical debris, thus causing the $Ca_3(PO_4)_2$ to settle quicker on the flume floor.

Batch 1 (25% latent fiber) was introduced in the flume before the test flume pump was started. The test flume was started five minutes after Batch 1 was placed in the flume. The fine particulate debris (batches 2-5), calcium silicate, walnut shell, tin, and dirt and dust were placed in the flume over 17 minutes. Two flume turnovers (approximately 12 minutes) after all of the particulate debris introduction was complete, the fine fibrous (batch 6) debris was placed in the flume. Five flume turnovers, approximately 30 minutes, after all of the fine fibrous debris was placed in the flume small fibrous (batch 7) debris was placed in the flume. After all of the non-chemical debris was placed in the flume the water level and flow rates were decreased to the low flow rate and level specified in the debris allocation table.

The test flume was run over night without any additional non-chemical or chemical debris introductions. Chemical batches consisted of ALOOH and $Ca_3(PO_4)_2$. ALOOH was used as a surrogate for sodium aluminum silicate in accordance with PCI document TD SSFS-TD-2007-004. ALOOH was introduced first followed by calcium phosphate two minutes after completion of the ALOOH introduction to ensure the ALOOH had cleared the debris introduction zone. Chemical injections were introduced in two flume turnovers, approximately 12 minutes, after the proceeding chemical batch was completed.

Batch # / Debris Type	Date	Time
1 Laten Fibers	4/28/2008	17:43
2 Calcium Silicate	4/28/2008	18:00
3 Walnut	4/28/2008	18:02
4 Tin	4/28/2008	18:08
5 Dirt and Dust	4/28/2008	18:14
6 Fine Fibers	4/28/2008	18:30
7 Small Fibers	4/28/2008	19:11
Flume Run over night with no debris additions		
8 Aluminum Oxyhydroxide	4/29/2008	8:43
8 Aluminum Oxyhydroxide Complete*	4/29/2008	8:48
8 Calcium Phosphate	4/29/2008	8:50
Batches 9 through 32 were introduced utilizing the same methodology as batch 8.	4/29/2008	8:43 - 21:39
Batches 32 through 58 were introduced utilizing the same methodology as batch 8.	4/30/2008	7:26 - 17:40
* Aluminum Oxyhydroxide introduction required ~6 minutes		

Table 22a-1: Debris Introduction Time Table

RAI-22b

Provide documentation of the head loss testing methodology, including;
Description of test facility.

RA-22b RESPONSE:

The test apparatus includes a test flume, two pumps (a main operating pump and a back up pump if the main pump fails. Both pumps do not operate in parallel), a prototype strainer, instrumentation & controls, and the associated piping and valves needed to complete a recirculation loop. The chemical injection system consists of; chemical mixing tanks, a peristaltic pump designated to pump the chemical debris into the test flume, and associated piping/tubing. To conservatively maintain a steady water level at or below the submergence water level during testing, an over flow weir (water management overflow Figure 22b-1) was installed at the upstream end of the test flume. Debris which may have transported past the overflow weir was captured by 5 and 10 micron bag filters located downstream of the overflow weir.

Figures 22b-1 through 22b-3 below depicted the test configuration utilized for St. Lucie Unit 2.

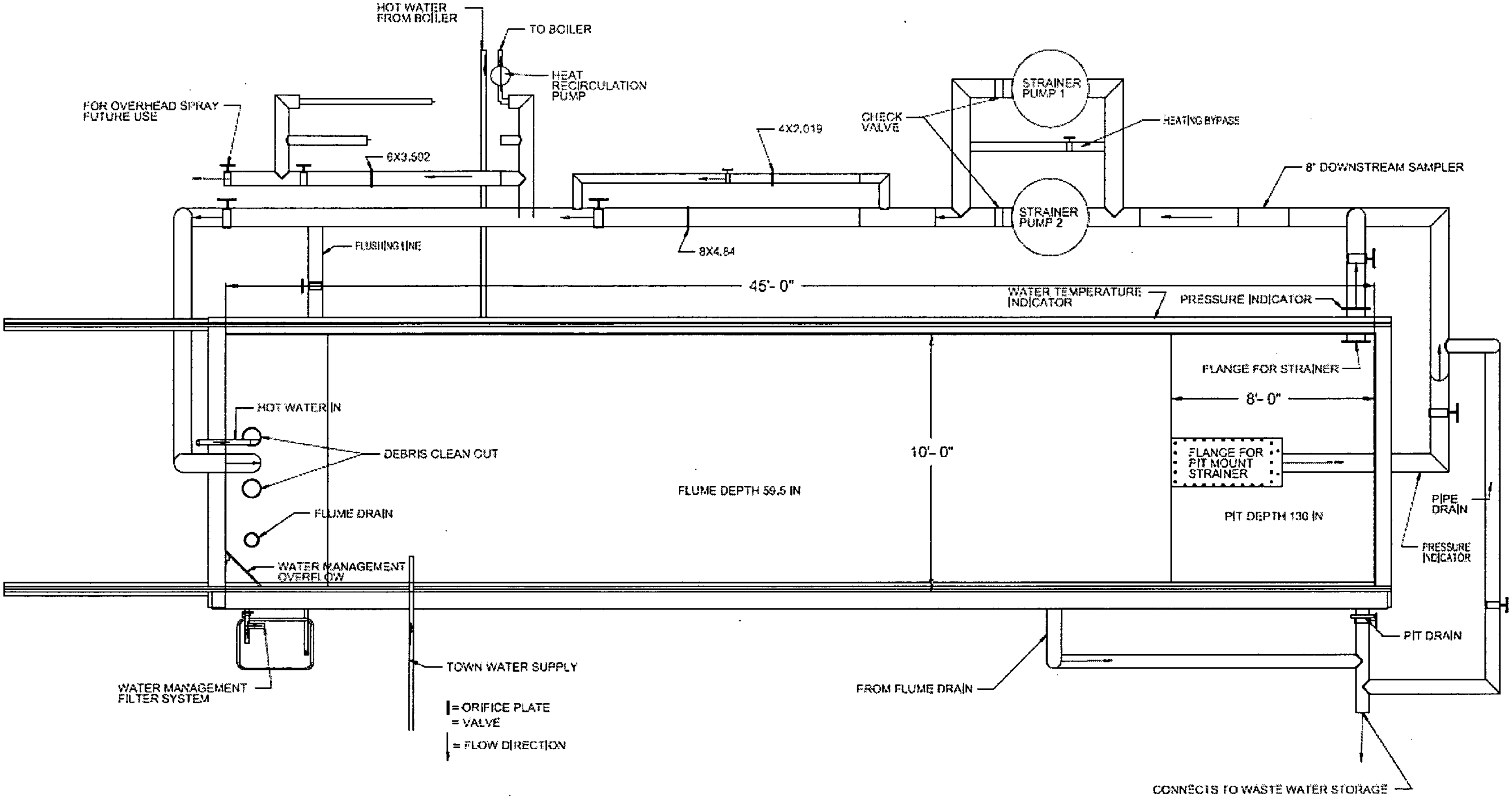
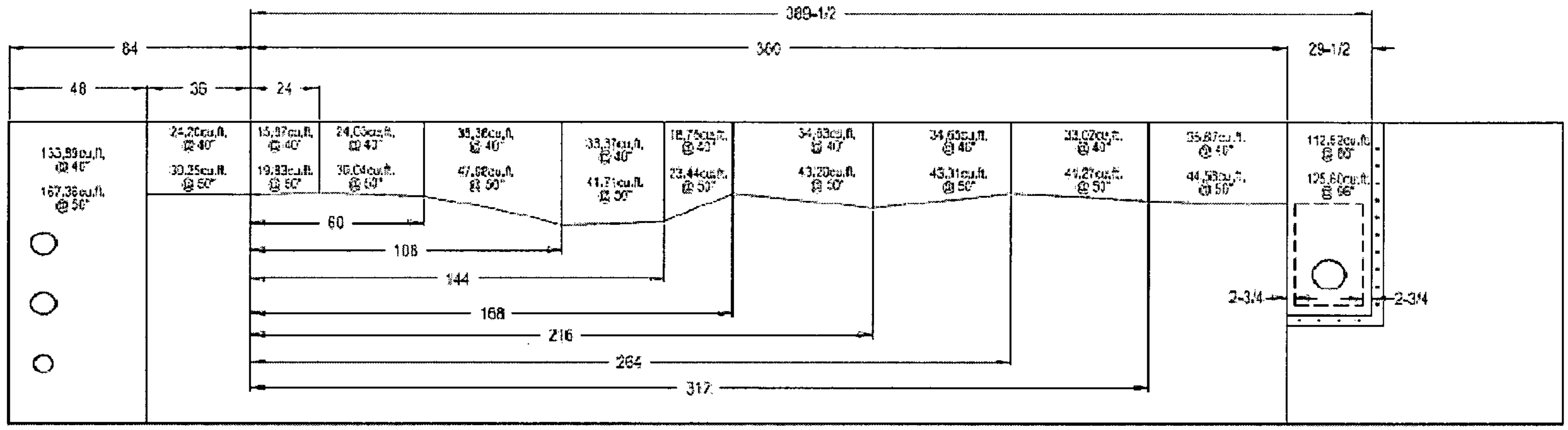
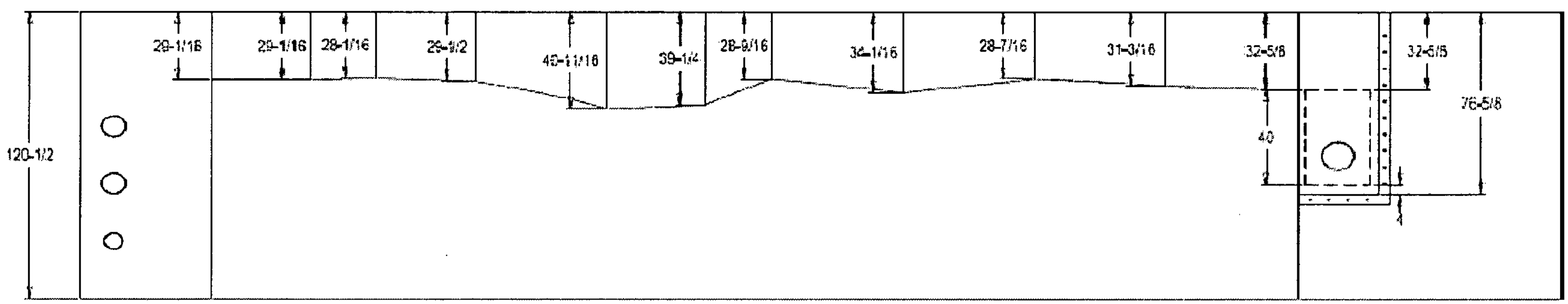


Figure 22b-1: Generic Test Flume Configuration (Top View)



Lengthwise Dimensions



Widthwise Dimensions

Figure 22b-2: St. Lucie Unit 2 Test Flume Wall Configuration (Top View)

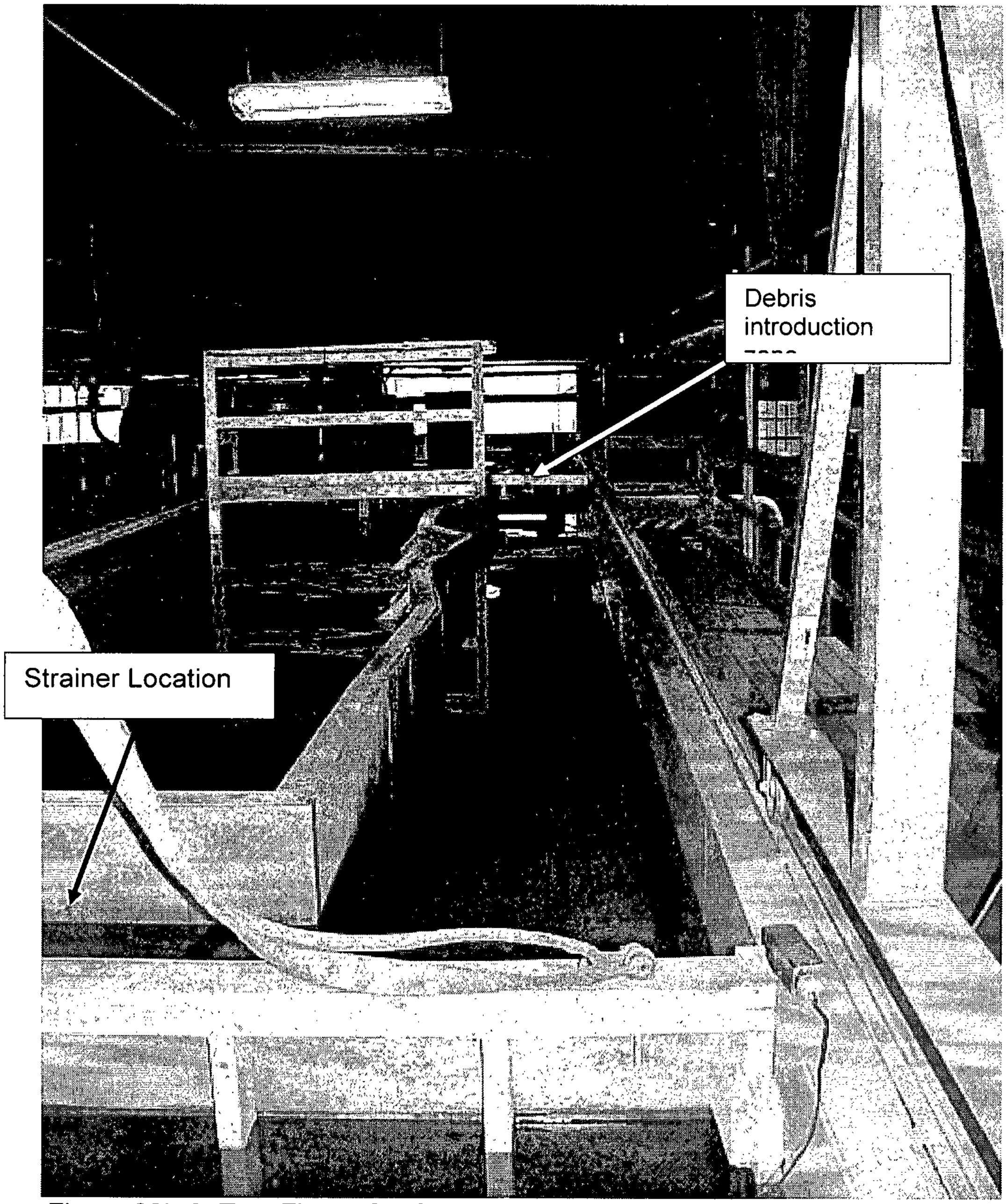


Figure 22b-3: Test Flume Configuration Looking Upstream of Strainer (Actual)

RAI-22c: Provide documentation of the head loss testing methodology, including; General procedure for conducting the tests.

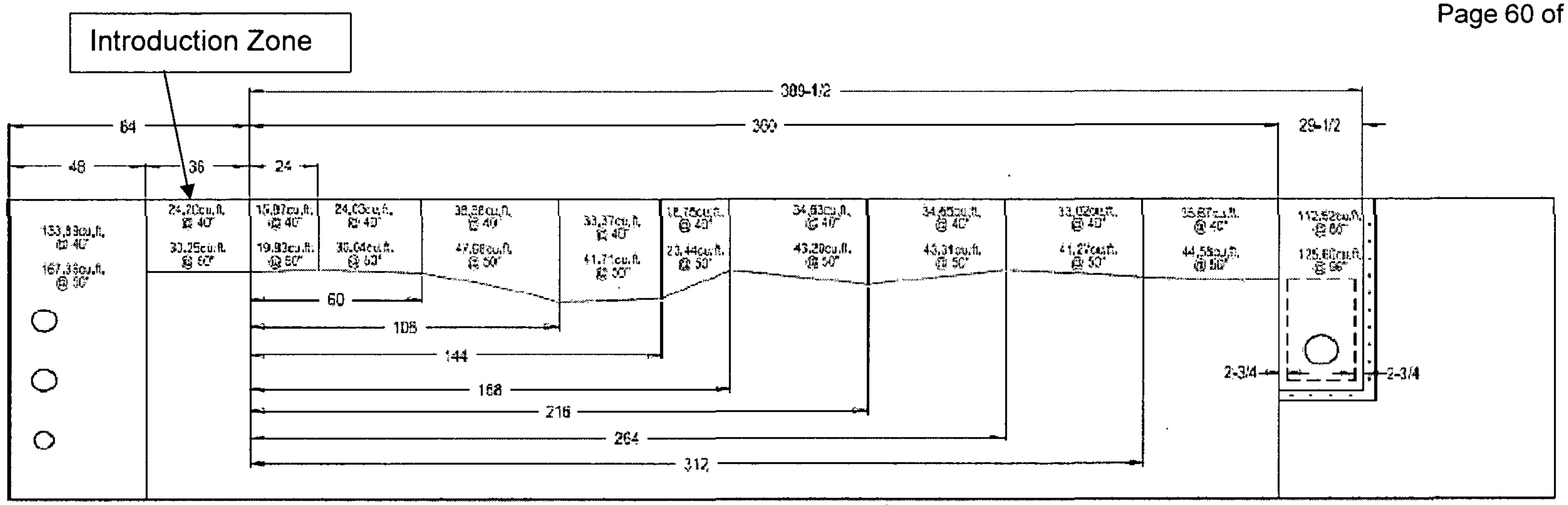
RAI-22c RESPONSE: The general procedure for conducting the debris laden strainer test is summarized below based on the AREVA Test Plan.

- 25% of the latent fibrous debris was introduced through the length of the test flume with the pump turned off for 5 minutes.
- The pump was turned on and the design flow rate is achieved in the test flume.
- All fine particulate debris was introduced into the test flume upstream of the strainer module.
- Following the fine particulate, the fine fibrous debris was introduced into the test flume upstream of the strainer module.
- After 5 flume turnovers all of the small fibrous debris was introduced into the test flume. Note a flume turnover was 5.97 minutes at the initial high flow state (LPSI failure to trip).
- Once all of the 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 injected into the flume in accordance with the methodology described in RAI response 22a. The chemical was injected into the flume at the debris introduction point indicated on figure 22d-1. Chemical batches consisted of ALOOH and calcium phosphate. ALOOH was introduced first followed by calcium phosphate two minutes after completion of the ALOOH introduction to ensure the ALOOH had cleared the debris introduction zone.

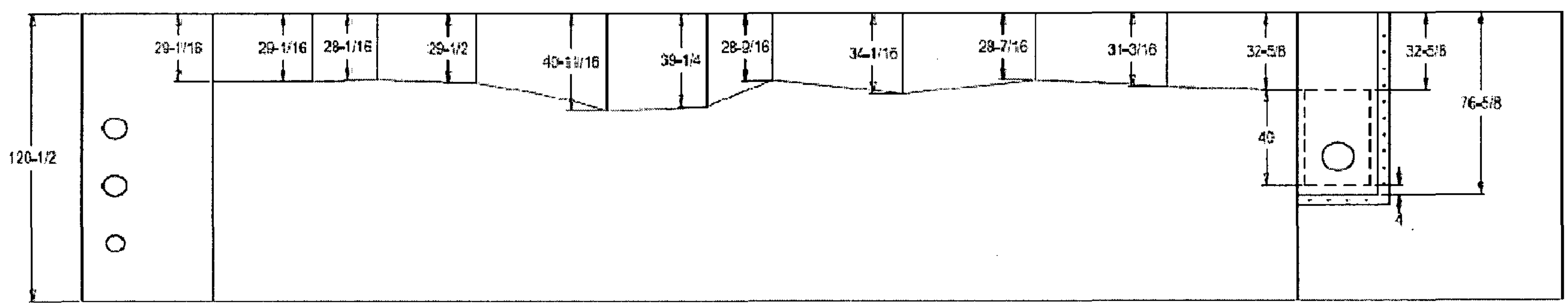
RAI-22d: Provide documentation of the head loss testing methodology, including; Debris introduction zones.

RAI-22d RESPONSE:

Batch 1, 25% latent fiber, was introduced along the length of the test flume. All other debris batches, were introduced into the test flume at the drop zone. See Figure 22d-1, below. The introduction zone was 389-1/2" inches upstream of the strainer module. The chemical debris was also introduced to the flume at the introduction zone indicated on Figure 22d-1 below.



Lengthwise Dimensions



Widthwise Dimensions

Figure 22d-1: Flume Configuration

RAI-22e: Provide documentation of the head loss testing methodology, including;

Fibrous debris size distribution and comparison to transport evaluation predictions showing that non-prototypical fiber sizes were not added to the test. [Note that for head loss testing and transportation evaluations the categories of small fines and large pieces may not provide sufficient information to adequately predict head loss and transportation effects. In general, small fines should be divided further into small pieces and fines.]

RAI-22e RESPONSE: The fibrous debris sizes used in testing were prototypical of the size distribution that was calculated using the assumptions and methodology contained in the St. Lucie 2 Nuclear Plant (PSL2) – Debris Transport calculation. The debris transport calculation uses the debris inputs from the FPL debris generation calculation and distributes the debris in two major steps. Step one is the debris size distribution and transportation due to initial blast, wash down, and pool fill. It is based on the guidance contained in NEI 04-07 volumes 1 and 2 and breaks the debris into two size groups small and large. Step two is the debris distribution due to containment sump recirculation, and is based on erosion of debris and the settling and incipient tumbling velocities contained in NUREG/CR-6772. The size distribution is further broken down into fines, small and large debris as a result of containment sump recirculation. The debris transport calculation determines the quantity and size of debris that are calculated to transport to the strainer.

The debris characteristic developed in St. Lucie Unit 2 debris transport calculation was used as design input for the PCI debris allocation tables. The debris allocation tables developed by PCI scale the debris types and sizes based on the debris transportation calculation.

For the St. Lucie Unit 2 strainer test, only small and fine fibers were introduced in the test flume. The quantity and size distribution were prototypical of the debris expected in the St. Lucie Unit 2 containment based on the transportation calculation completed for St. Lucie Unit 2. See RAI 22f, Figure 22f-1for the as tested fibrous debris size distribution and quantities of small and fine fiber.

RAI-22f: Provide documentation of the head loss testing methodology, including;

Particulate debris size distributions

RAI 22f RESPONSE: The particulate debris size distribution for the debris laden test was established in the calculation St. Lucie 2 Nuclear Plant (PSL2) –Debris Transport calculation. This distribution was then utilized in establishing the debris distribution for the test. The debris allocation table is shown below for illustration as figure 22f-1.

The calcium silicate size is specified by individual licensees. For St. Lucie Unit 2 calcium silicate powder was utilized.

The qualified concrete epoxy and unqualified epoxy coating surrogate was #325 walnut shell flour or similar.

The qualified steel epoxy, qualified inorganic zinc coatings, and unqualified inorganic zinc coatings surrogate was tin powder with a size range of 10 – 44 microns.

TDI-6018-01 Rev 0 — ATTACHMENT 1 — Test 2 Maximum Debris

Test Plan Debris Allocation — Page 4

High Fiber Design Condition — 2 — Type of Test; 1 = Thin Bed; 2 = High Fiber; 3 = CSHL

Debris Type	U/M	Quantity	Wt Conversions (lbs / ft³ or ft²)	Debris Scaled to Test Module	Debris Qty + 0%	U/M	Debris Form / (Surrogate)
Fibers (Design Basis)							
NUKON (Fines)	ft³	281.69	2.4	68.156	68.156	lbm	Fiber thru Debris Shredder
NUKON (Smalls)	ft³	274.66	2.4	66.455	66.455	lbm	Fiber thru Debris Chipper
NUKON (Larges)	ft³	0.00	2.4	0.000	0.000	lbm	Fiber thru Debris Chipper
NUKON (Intact)	ft³	0.00	2.4	0.000	0.000	lbm	Fiber thru Debris Chipper
Latent Fibers	lbm	12.600	n/a	1.270	1.270	lbm	Fiber thru Debris Shredder (15% of Latent)
				Total Fibrous Debris	135.881		NOTE: 14.04 lbs of fibrous debris is required to obtain a theoretical thin bed of 0.125".
Particulates							
Cal-Sil	ft³	10.59	14.5	15.480	15.480	lbm	Cal-Sil Powder
Latent Particulate; Dirt & Dust	lbm	71.600	n/a	7.220	7.220	lbm	PCI PWR Dirt Mix (85% of Latent Debris)
Coatings (lbs)							
Qualified Coatings - Concrete - Epoxy	ft³	5.26	94	49.850	49.850	lbm	Powder (Walnut Shells or Acrylic Coating)
Qualified Coatings - Steel - Epoxy	ft³	0.85	94	8.000	8.000	lbm	Powder (Tin Powder)
Qualified Coatings - Steel - IOZ	ft³	0.48	457	22.110	22.110	lbm	Powder (Tin Powder)
Unqualified Coatings - Epoxy	ft³	6.22	94	58.940	58.940	lbm	Powder (Walnut Shells or Acrylic Coating)
Unqualified Coatings - IOZ	ft³	2.74	457	126.240	126.240	lbm	Powder (Tin Powder)
				Total Particulate Debris	288.840		
Chemical Debris Concentrations							
Sodium Aluminum Silicate	lbm	650.01	n/a	65.53	65.53	lbm	WCAP Chemical Surrogate - AlOOH
Calcium Phosphate	lbm	408.80	n/a	41.21	41.21	lbm	WCAP Chemical Surrogate - $Ca_3(PO_4)_2$
Aluminum Oxyhydroxide	lbm	127.21	n/a	12.82	12.82	lbm	WCAP Chemical Surrogate - AlOOH
				Total WCAP Surrogate Debris	119.56	lbm	
Miscellaneous Debris							
Lables, Stickers, Tape, Placards, Tags	ft²	44.500	n/a	4.486	4.486	ft²	By FPL - sizes, types & quantities
Glass	ft²	0.000	0.04305	0.000	0.000	lbm	By FPL - type & size
Adhesives	ft²	0.000	n/a	0.000	0.000	lbm	Not considered per FPL
RMI (Smalls)	ft²	1214.800	0.0813	9.957	9.957	lbm	1/4", 1/2" & 1" square pieces
RMI (Larges)	ft²	0.000	0.0813	0.000	0.000	lbm	2", 4" & 6" square pieces
Insulation Jacketing (Smalls)	ft²	0.000	0.0813	0.000	0.000	lbm	1/4", 1/2" & 1" square pieces
Insulation Jacketing (Larges)	ft²	0.000	0.0813	0.000	0.000	lbm	2", 4" & 6" square pieces

PUMP FLOW RATE @ START UP — gpm — 864.0 — 5.97 minutes for 1 pool turnover — 501.1 gpm - 9.71 minutes / 1 turnover; 138.2 gpm - 35.22 minutes / 1 turnover

Other Conditions			Test Module SFS-TU22			Reference for Design Input
Surface Area for Debris	ft²	5607.20	N/A			TDI-6018-02, Rev. 1
Net "Effective Surface Area"	ft²	5607.20	555.200	10.0813%	Scaling Factor	TDI-6018-02, Rev. 1
Pump Flow (Thin Bed Test)	gpm	8570.00	864.0	Scaling Factor Applied		TDI-6018-02, Rev. 1
Pump Flow (Thin Bed Test)	gpm	4970.00	501.1	Scaling Factor Applied		TDI-6018-02, Rev. 1
Pump Flow (Thin Bed Test)	gpm	1370.00	138.2	Scaling Factor Applied		TDI-6018-02, Rev. 1
AV @ Effective Screen Area	ft / sec	0.0035	0.0035			
Limiting NPSH Margin Available	feet	2.98				210 °F
Post LOCA Temperature for HL Calc		120 ° F				Flume temperature for testing
Est Fiber Quantity for 0.125 in thick Bed on ESA	ft³	57.4	5.78			
Screen Submergence	in	16.46				SFS-TU22-GA-00A Sht 2 of 2
Distance from Floor To Bottom of First Disk Face	in	1.00				SFS-TU22-GA-00A Sht 2 of 2
Estimated Flume Water Level	ft	50" / 46"				50" for 873.6 gpm / 46" for 506.0 gpm & 139.7 g

Sump Operating Conditions Assumed		
Total Number of Sumps or Trains	2	
Sumps or Trains Operating	1	
Quantity of Strainers Operating	8	8 is the number of modules operating
Are Screens Redundant?	Yes	
Is Debris Transport Part of Protocol?	Yes	Do Not Run Overhead Mixing Pipes

Created By / Date	C A Kudla	4/25/08
Checked By / Date	[illegible]	4/25/08
Approved By / Date	[illegible]	4/25/08

Figure 22f-1: Debris Laden Debris Allocation Table

RAI-22g: Provide documentation of the head loss testing methodology, including; Amounts of each debris type added to each test

RAI-22g RESPONSE: For St. Lucie Unit 2 one design basis debris laden test was completed. This test was completed in accordance with the AREVA test plan and the results were documented in strainer test report. The following debris was placed in the flume as summarized in the strainer test report.

Batch 1: ~25% of PSL2 latent fibrous debris (Nukon fine fiber, .33 lbm)

Fine Particulate Debris

Batch 2: 100% PSL2 Cal-Sil (15.50 lbm)

Batch 3: 100% of PSL2 Walnut Shell particulate debris (108.75 lbm).

Batch 4: 100% of PSL2 Tin particulate debris (157.5 lbm)

Batch 5: 100% of PSL2 Dirt & Dust (7.25 lbm)

Fine Fibrous Debris

Batch 6: 100% of PSL2 fine Nukon fibers and the remainder (75%) of the Latent fibrous debris (~68.3 lbm)

Small Fibrous Debris

Batch 7: 100% of PSL2 small Nukon fibers. (68.40 lbm)

Chemical Precipitate Debris

ALOOH was introduced into the test flume over a two day span in small batches of 24 gallons and 14.5 gallons. The first three batches of ALOOH were batched into the test flume at a volume of 24 gallons. The remaining batches to complete all ALOOH introductions were batched into the test flume at a volume of 14.5 gallons. The purpose for these batch volumes was to prevent the flume from becoming overly concentrated with chemical debris, thus causing the ALOOH to settle quicker on the flume floor.

$Ca_3(PO_4)_2$ was introduced into the test flume over a two day span in small batches of 28 gallons and 17 gallons. The first three batches of $Ca_3(PO_4)_2$ were batched into the test flume at a volume of 28 gallons. The remaining batches to complete all $Ca_3(PO_4)_2$ introductions were batched into the test flume at a volume of 17 gallons. The purpose for these batch volumes was to prevent the flume from becoming overly concentrated with chemical debris, thus causing the $Ca_3(PO_4)_2$ to settle quicker on the flume floor

A total of 81.89 lbm of ALOOH was added to the test flume utilizing the methodology above. A total of 43.07 lbm of $Ca_3(PO_4)_2$ was added to the flume utilizing the methodology above.

RAI-22h: Provide documentation of the head loss testing methodology, including;
Test strainer area.

RAI-22h RESPONSE: The net "effective surface area" of the test strainer was 555.2 ft^2.

RAI - 22i: Provide documentation of the head loss testing methodology, including; Test flow rates.

RAI-22i RESPONSE: The initial test flow rate was 864.0 gpm to account for a LPSI pump failure to trip, and subsequently 501.1 gpm. A tolerance of -0% +5% was applied to the testing flow rate to ensure conservatively high flow rates were maintained throughout the test.

RAI-22 j: Provide documentation of the head loss testing methodology, including; Description of debris introduction including debris mixes and concentrations showing that non-prototypical agglomeration did not occur.

RAI-22j RESPONSE: The St. Lucie Unit 2 strainer test plan provides the instructions to pre-wet all non-chemical debris.

Each batch of "fines", and "smalls" non-chemical debris was combined with water and stored for introduction to the flume to help remove trapped air.

Fibrous debris was prepared in accordance with specific steps of the test plan to ensure sufficient water was added to the fiber to prevent agglomeration of the fine fibers, and is shown below for clarity.

> "***DILUTE*** *the fine fibrous debris with hot water (~120 °F) to approximate 3 parts water and 1 part fibrous debris (by volume) using the following steps:*
>
> - ***MIX*** *the fibrous debris and heated city water in mixing containers in order to pre-mix the fibrous debris*
> - ***FILL*** *a 5 gallon bucket with 3 gallons of heated city water.*
> - ***PLACE*** *1 gallon of pre-mixed fibrous debris into the 5 gallon bucket.*
> - ***RE-MIX*** *5 gallon bucket with a paddle mixer, or a paint mixer hooked up to an electric drill (or equivalent), then introduce into the test flume.*
>
> ***REPEAT*** *these steps until all the fine fibrous debris has been diluted."*

The diluted fine fiber was mixed with a paddle mixer attached to an electric drill to prevent agglomeration of the fine fiber. The particulate debris was also pre-wetted and mixed using a paddle mixer attached to an electric drill. The particulate and fibrous debris was also rinsed out of the holding containers during debris introductions to prevent the debris from agglomerating while entering the test flume.

RAI-22k: Provide documentation of the head loss testing methodology, including;

Flow velocity profile in the flume as compared to plant flow velocities in the areas adjacent to the strainer.

RAI–22k RESPONSE: The plant strainer approach velocities were calculated in the AREVA debris transport calculation. The following was extracted from that calculation:

"The calculation of the St. Lucie Nuclear Power Plant Unit 2 (PSL2) Sure Flow Strainer qualification test program flume configuration utilizes the results of the CFD debris transport study to define the average approach velocities to the strainer. The following methodology is applied:

1. *Use the CFD post-processing software to numerically seed each active module train face with massless tracer particles (massless tracer particles show the direction of the flow at every point along their path).*
2. *Back-calculate the trajectory of the particles to define streamline traces to each module. This identifies the path the water follows to each strainer module face.*
3. *With the water path to each module identified, use the CFD post-processing software to define vertical planes at 1 ft increments back from the module train, along the paths defined in (2).*
4. *Trim each plane such that the velocities within that plane are those which convey water to the module.*
5. *At each 1 ft increment back from the module train, record the cross section average of the velocity magnitude across that plane. If the paths diverge around objects in the flow, follow each bifurcated path individually. Record these averages over a total of 30 ft back from the module train.*
6. *Using a spreadsheet, calculate the weighted average of the four flow streams at each 1 ft increment. The average at each increment is weighted by twice the fastest velocity at the increment under consideration. Weighting the average by twice the fastest velocity incorporates conservatism into the calculation.*
7. *Create a plot of the calculated weighted average velocity defined in (6) vs. incremental distance back from the module train.*
8. *Using engineering judgment, create up to 9 linear line segments which conservatively represent the velocity trends over the 30 ft distance.*
9. *Calculate the width of the test flume at each line segment break using the following expression:*

$$Q = VA$$

Where:
Q = Total flow to test module (ft3/s)
A = Flume cross sectional area (ft2)
V = Weighted cross sectional average velocity (ft/s)

And:

A = WH

Where:
W = Flume width (ft)
H = Water surface height in the test flume (ft)

10. *Create a table of flume width vs. line segment length to be used in defining the shape of the flume."*

The results of this method are provided in the form of a graph below. NOTE: the WT AVG Velocity is the weighted average plant approach velocity.

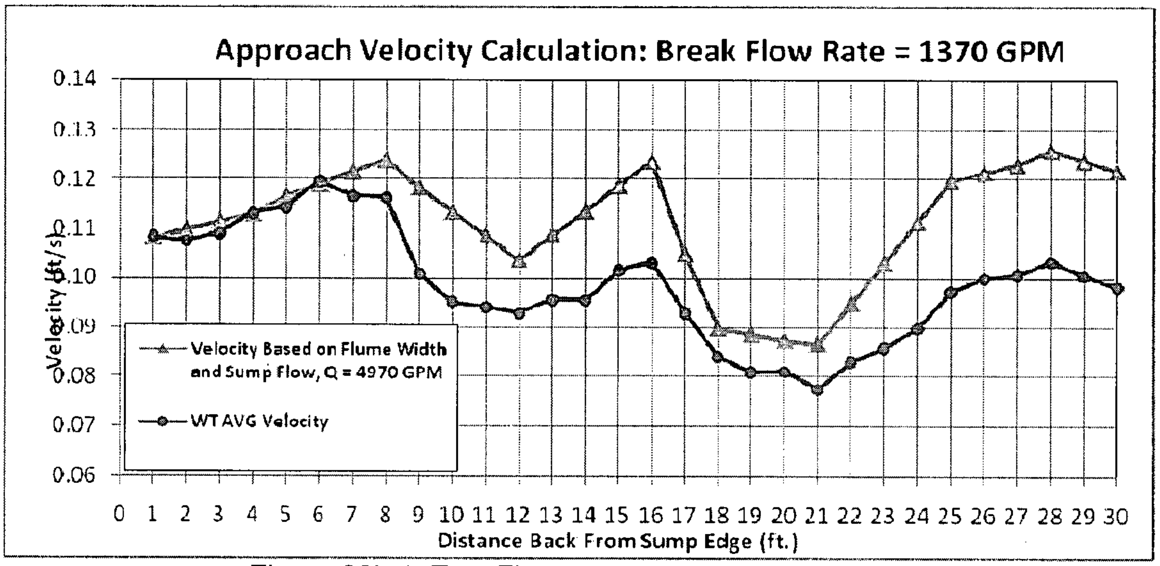


Figure 22k-1: Test Flume Approach Velocities for low flow

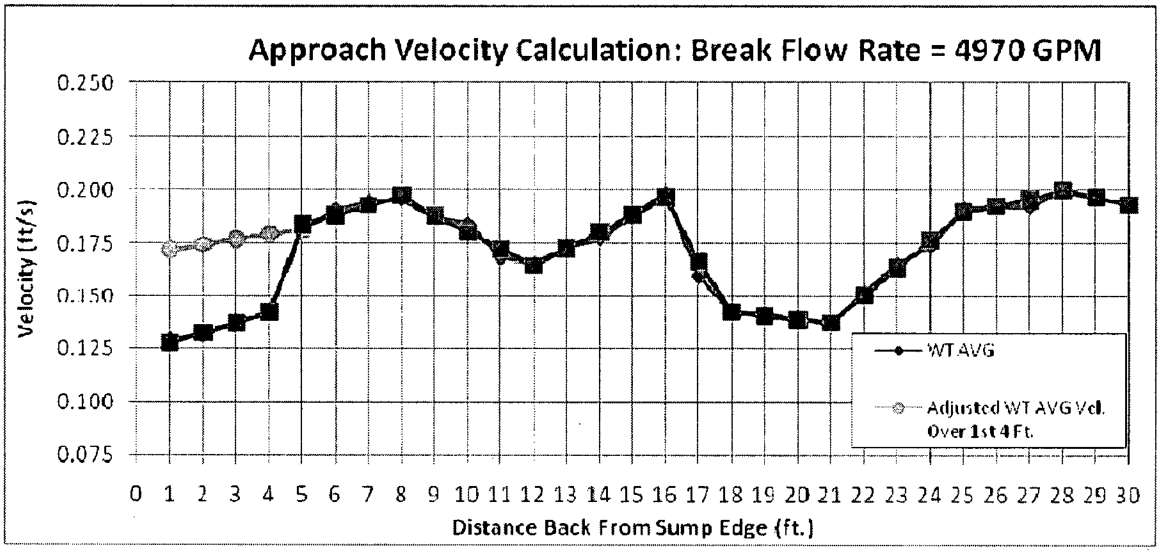


Figure 22k-2: Test Flume Approach Velocities for high flow

Conclusion: The test flume width was constructed such that, for a given water level and test module flow, the approach velocities at each cross section matched the curve given in Figure 22k-2 or were conservative.

RAI-23: Provide the details of both the methodology and results for the thin bed search tests that were conducted. Include the incremental amounts of fibrous debris added along with the number of flume turnovers between additions.

RAI-23 RESPONSE: For St. Lucie Unit 2 thin bed testing was not performed based on the performance of the design basis test. It was concluded after the design basis debris loaded strainer test that open strainer surface was observed. Therefore, a thin bed had not formed when subjected to the full debris load. Figure 23-1 below documents the strainer surface area observed after the design basis test was complete.

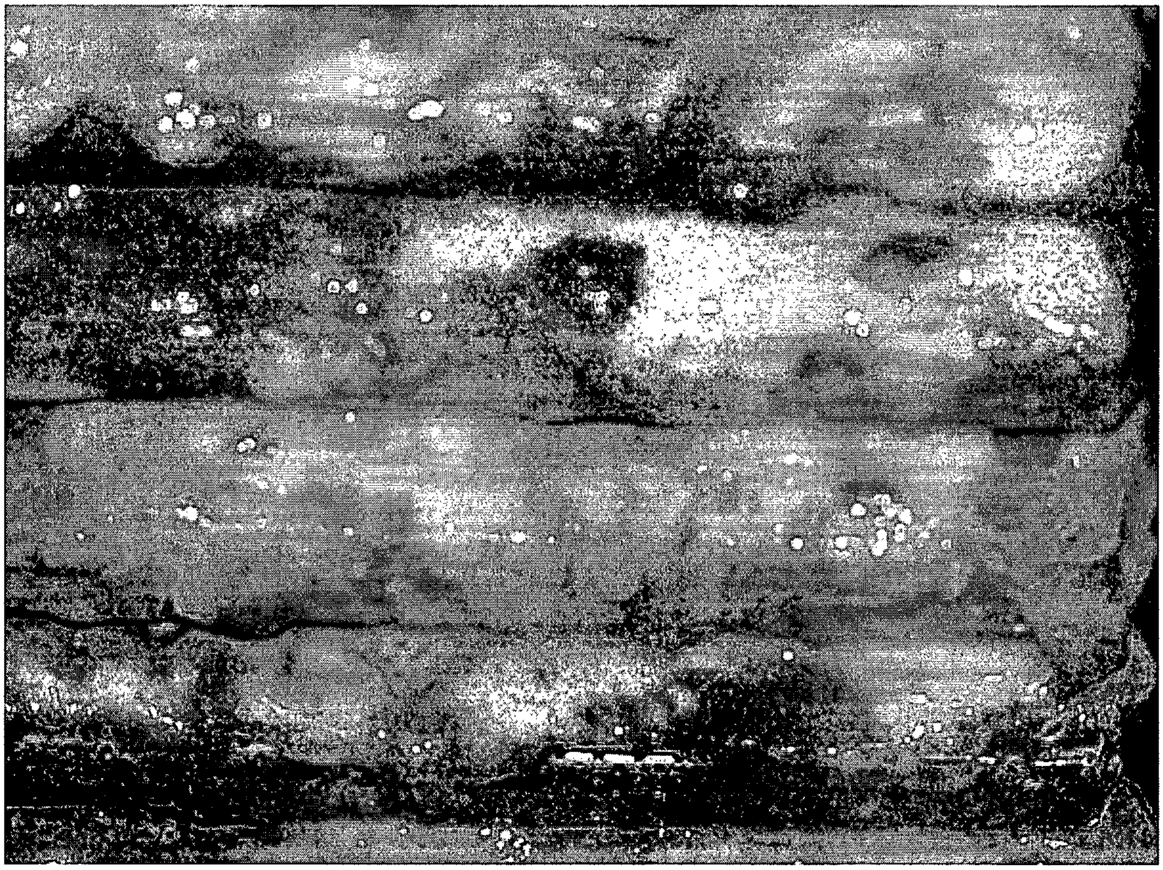


Figure 23-1: Close up of Debris Laden Strainer

The design load debris, was introduced in the following order.

Batch 1: ~25% of PSL2 latent fibrous debris (Nukon fine fiber, .33 lbm).

Wait five minutes and start strainer recirculation pump.

Fine Particulate Debris

Batch 2:	100% PSL2 Cal-Sil (15.50 lbm)
Batch 3:	100% of PSL2 Walnut Shell particulate debris (108.75 lbm).
Batch 4:	100% of PSL2 Tin particulate debris (157.5 lbm)
Batch 5:	100% of PSL2 Dirt & Dust (7.25 lbm)

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Fine Fibrous Debris

Batch 6: 100% of PSL2 fine Nukon fibers and the remainder (75%) of the Latent fibrous debris (~68.3 lbm)

Five (5) pool turnovers or thirty (30) minutes passed before small fibrous debris was placed in the flume.

Small Fibrous Debris

Batch 7: 100% of PSL2 small Nukon fibers. (68.40 lbm)

The flume was run over night with no additional chemical or non-chemical debris introductions.

Chemical Precipitate Debris

Chemical batches consisted of ALOOH and $Ca_3(PO_4)_2$. ALOOH was introduced first followed by calcium phosphate two minutes after completion of the ALOOH introduction to ensure the ALOOH had cleared the debris introduction zone. Chemical injections were introduced two flume turnovers, approximately 12 minutes, after the proceeding chemical batch was completed.

ALOOH was introduced into the test flume over a two day span in small batches of 24 gallons and 14.5 gallons. The first three batches of ALOOH were batched into the test flume at a volume of 24 gallons. The remaining batches to complete all ALOOH introductions were batched into the test flume at a volume of 14.5 gallons. The purpose for these batch volumes was to prevent the flume from becoming overly concentrated with chemical debris, thus causing the ALOOH to settle quicker on the flume floor.

$Ca_3(PO_4)_2$ was introduced into the test flume over a two day span in small batches of 28 gallons and 17 gallons. The first three batches of $Ca_3(PO_4)_2$ were batched into the test flume at a volume of 28 gallons. The remaining batches to complete all $Ca_3(PO_4)_2$ introductions were batched into the test flume at a volume of 17 gallons. The purpose for these batch volumes was to prevent the flume from becoming overly concentrated with chemical debris, thus causing the $Ca_3(PO_4)_2$ to settle quicker on the flume floor.

Fiber bypass testing was conducted in accordance with the St. Lucie Unit 2 Strainer Test Plan. Fiber bypass testing placed the same amount and types of fibrous debris in the flume as the design basis test (reference 3, attachment 1, test 1B and test 2). While this test was not designed to create a 0.125" thin bed it demonstrates the 100% fiber load does not create a thin bed and results in clean strainer area as documented in figure 23-2 below.

For Test 2 all batches were introduced at the drop zone, upstream of the prototype strainer. The order for debris introduction, along with the measured amounts, were extracted from the AREVA test plan:

Batch 1: Fine Nukon fibers (8.55 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 2: Fine Nukon fibers (8.55 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 3: Fine Nukon fibers (8.55 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 4: Fine Nukon fibers (8.55 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 5: Fine Nukon fibers (8.50 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 6: Fine Nukon fibers (8.50 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 7: Fine Nukon fibers (8.50 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 8: Fine Nukon fibers (8.50 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 9: Small Nukon fibers (8.60 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 10: Small Nukon fibers (8.55 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 11: Small Nukon fibers (17.00 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 12: Small Nukon fibers (17.00 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

Batch 13: Small Nukon fibers (17.00 lbm).

Two (2) pool turnovers or twelve (12) minutes passed before introducing fine fibrous debris in the flume.

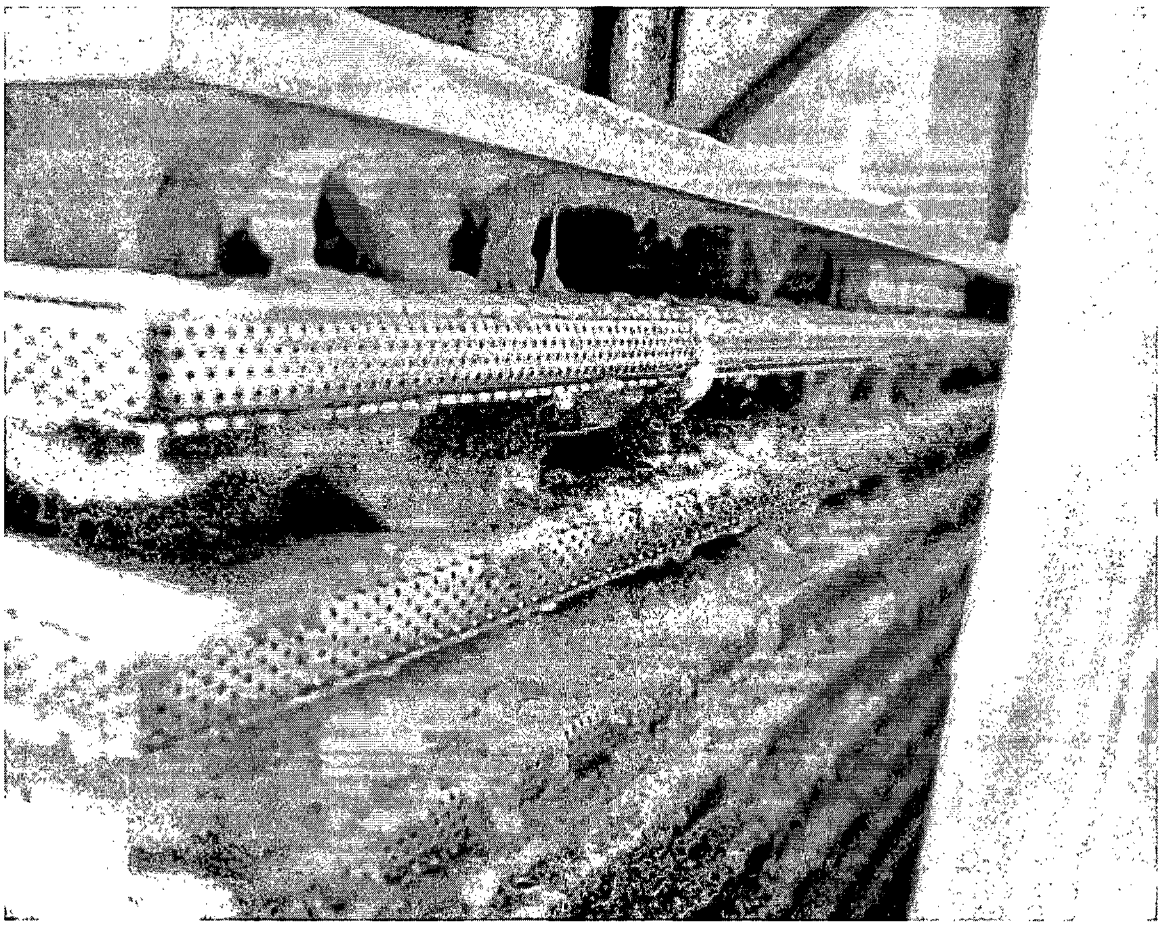


Figure 23-2: Strainer Post Fiber Bypass test

RAI-24: Provide a graph of the head loss testing for the duration of the chemical effects test including the non-chemical portions. Include information regarding events that would be expected to affected strainer debris bed head loss such as debris addition, large flow changes, etc.

RAI-24 RESPONSE: The head loss curve is presented below as Figure 24-1, the curve was developed with the raw data collected while testing and documented in the test plan.

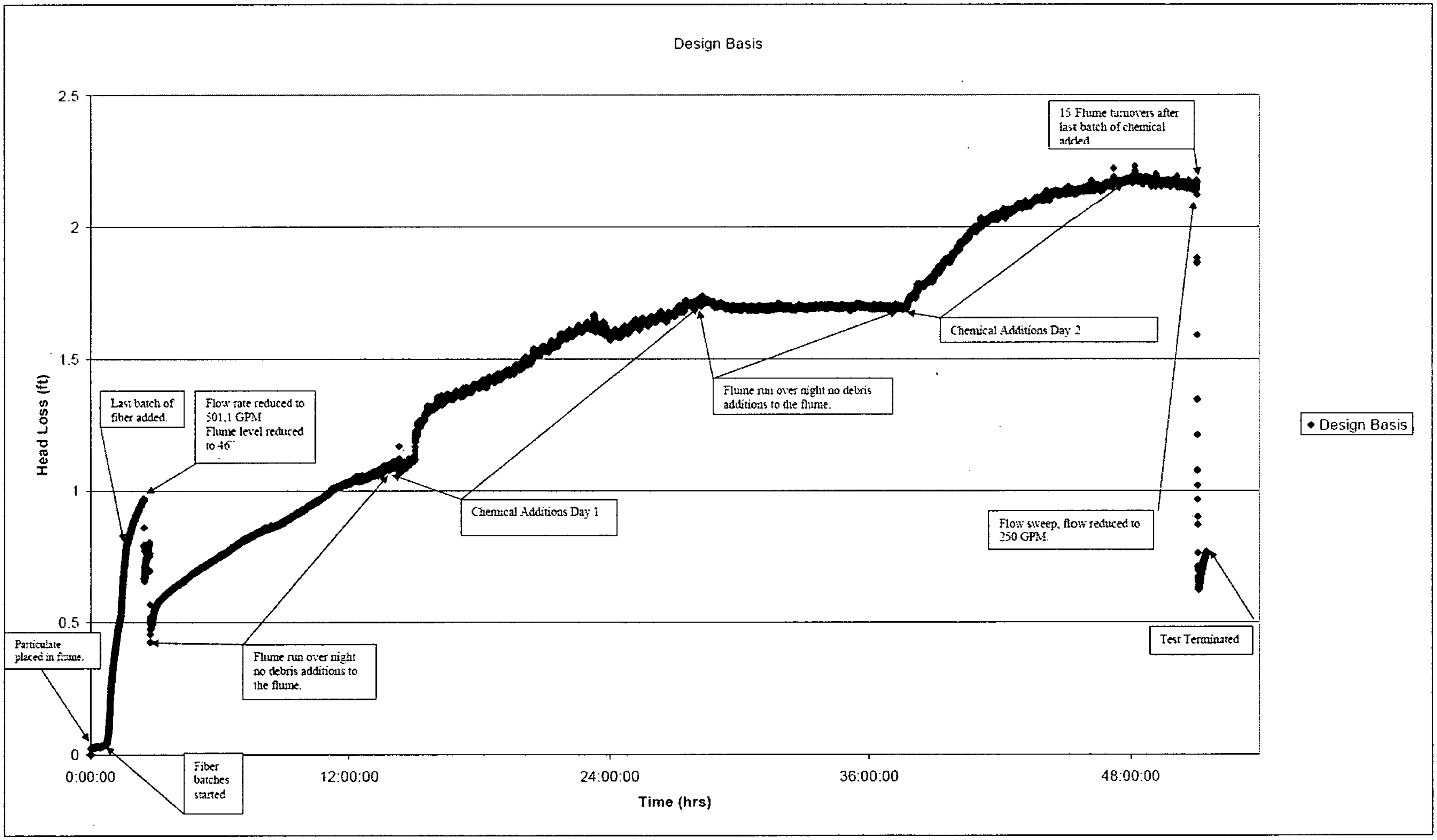


Figure 24-1: Head Loss Versus Time For PSL2

RAI-25: The supplemental response stated that credit was taken for near-field settling. Provide the estimated amount (lbm) of debris that settled in the test flume.

RAI-25 RESPONSE:

The amount of debris that settled due to near term settling was not collected and dried to determine the amount of debris that settled due to near-field settling. The industry guidance provided in NEI 04-07 did not require that an estimate, determination or calculation of the percentages of materials that settled in the flume. Figure 25-1 below depicts the debris that settled out due to near term settling.

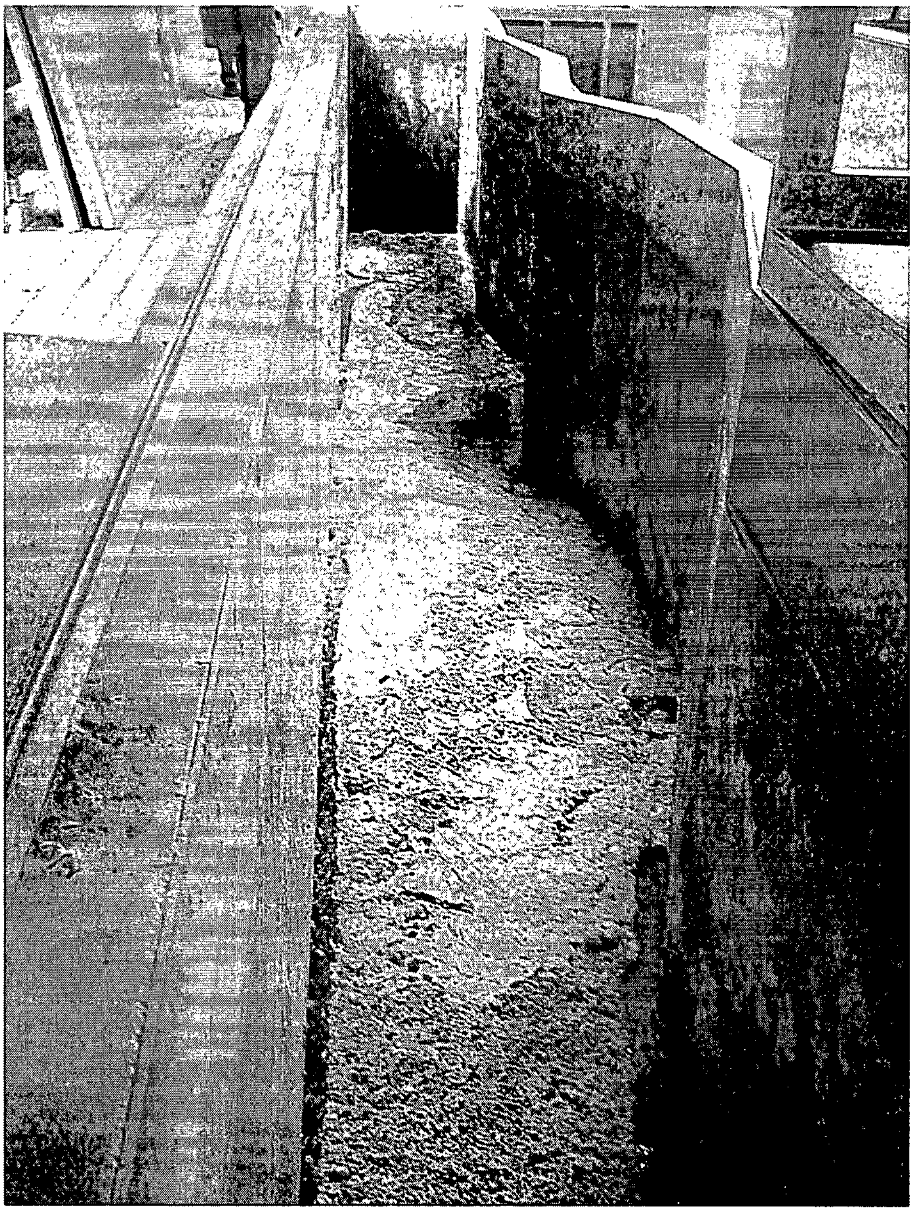


Figure 25-1: Debris in test flume post test

RAI-26: The strainer submergence and vortexing evaluation included the volume of the Safety Injection Tanks (SIT) for the small-break LOCA. It is possible for some breaks that this volume would not be available for sump pool inventory. Provide a justification for the crediting of SIT volumes for sump pool level for all required breaks.

RAI-26 RESPONSE : The range of small-break LOCA (SBLOCA) breaks includes those that require recirculation from the containment sump as well as those that permit the operators to depressurize the RCS and initiate the shutdown cooling mode of decay heat removal, which does not require suction from the containment sump. Because the SBLOCA produces less debris, the debris load on the sump strainers is less than the design basis debris load. However, for the purpose of evaluating the sump strainer under SBLOCA conditions, it is conservatively assumed that the recirculation flow from the containment sump and the debris load are the same as the LBLOCA, and that the water level is that of the SBLOCA.

For breaks so small that RCS pressure can be maintained above the safety injection tank (SIT) pressure (thus preventing outflow) using high pressure safety injection (HPSI) pumps and/or charging pumps, system flows and debris generation are minimal as compared to the LBLOCA design basis. During the injection mode, this RCS pressure would be above the shutoff head of the LPSI pumps stopping flow and would reduce flow from the HPSI pumps. Containment pressure would be insufficient to generate containment spray actuation signal (CSAS) or would be mitigated so rapidly as to allow early termination of the containment spray pumps. With elevated RCS pressure, RCS cooling can be accomplished with steam generators and/or the shutdown cooling system. Considering such reduced flows from this very small break, the time to actuation of RAS is significantly delayed beyond the LBLOCA design of 20 to 30 minutes. For example, with 386,734 gallons of usable RWT volume, and even the equivalent of full HPSI pump flow (685 gpm) liquid small break, it would take 9.4 hours to consume the RWT, which is sufficient time to cool the plant without switching to recirculation mode.

Even if you assume that SIT volumes do not discharge and spill through this break to the containment pool and that recirculation mode is for some reason still required, the resultant post SBLOCA containment water level without SIT volume is approximately 22.2 ft versus approximately 23.00 ft.

Based on the St. Lucie Unit 2 vortex calculation and general arrangement drawing, the strainer system high point is at elevation 21 ft. 10 7/16 inches which would be still submerged without SIT volume contributions. For the very small break flow rates, approach velocities are no where near a vortex issue and submersion precludes air ingestion. Therefore, it can be concluded that the full RCS blowdown and SIT discharge SBLOCA with higher flows and debris is bounding from a GSI 2004-02 perspective.

<u>RAI-27:</u> The supplemental response stated that the test cases were observed and photographed to ensure the absence of bore holes. However, bore holes normally cannot be detected visually. Additionally, the supplemental response stated that a thin bed did not form during testing. It is unclear from the supplemental response whether there was clean strainer area after all debris was added. In order to assure that viscosity correction is applicable to the test results, flow sweeps should have been conducted at the conditions from which extrapolations are conducted. Provide additional justification that bore holes did not occur during testing (e. g., flow sweeps were conducted with acceptable linear results). Also, if boreholes or significant clean strainer areas occurred. Provide an evaluation of how these debris bed characteristics would affect the results of the extrapolation to higher fluid temperatures.

<u>RAI-27 Response:</u> Flow sweeps were conducted just prior to strainer test termination as directed by St. Lucie Unit 2 test plan. As documented in the St. Lucie Unit 2 Test Report bore holes and other differential pressure inducing effects were not observed. Calculations showed that the change in head loss was proportional to the ratio of the flow rates squared which indicates that bore holes and other differential pressure inducing effects did not exist.

Figure 27-1, below, provides a general strainer debris load view post test, and figure 27-2, below, provides a close up view of the clean strainer surface area observed post testing.

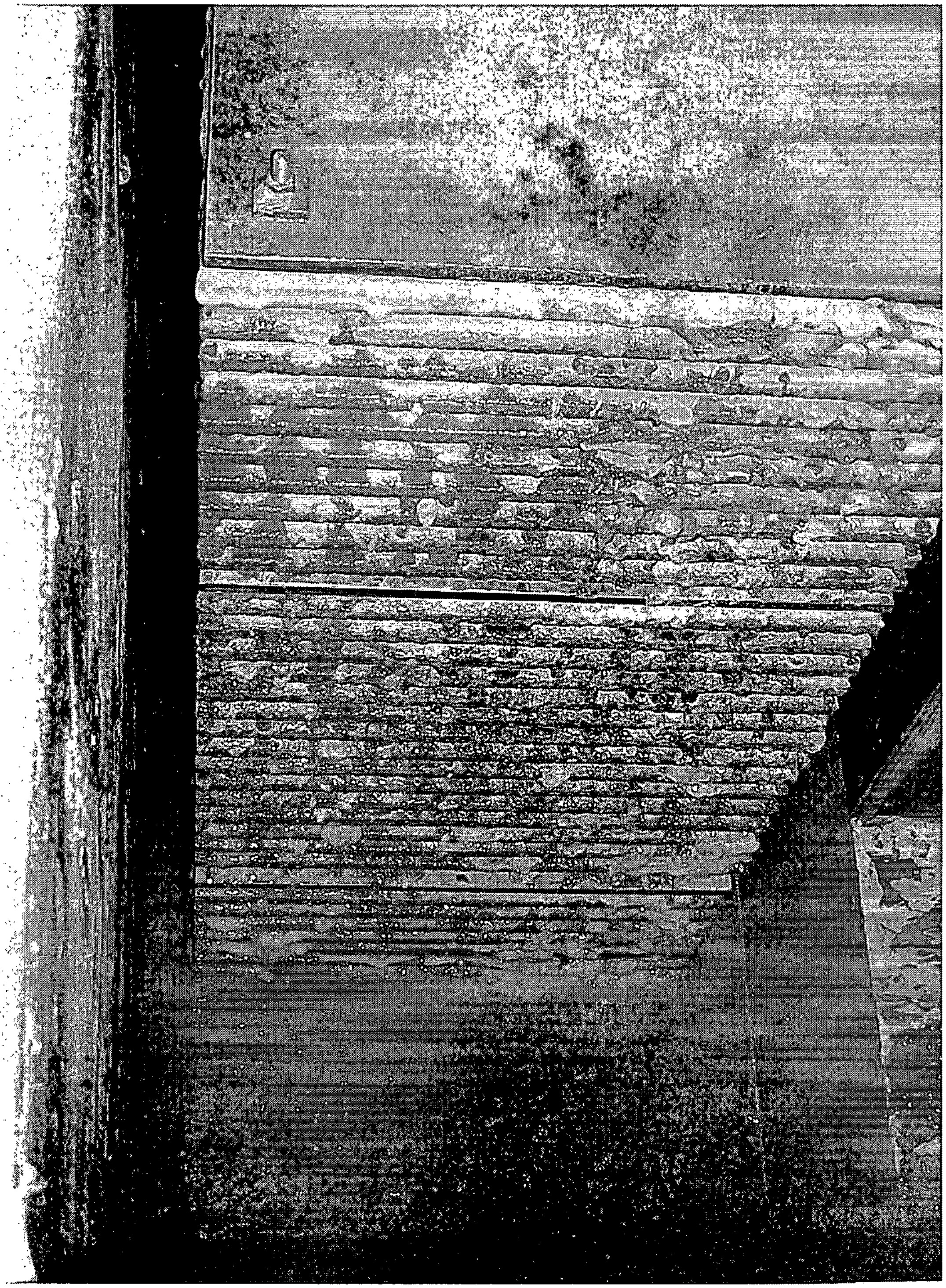


Figure 27-1: Debris Laden Strainer Post Test

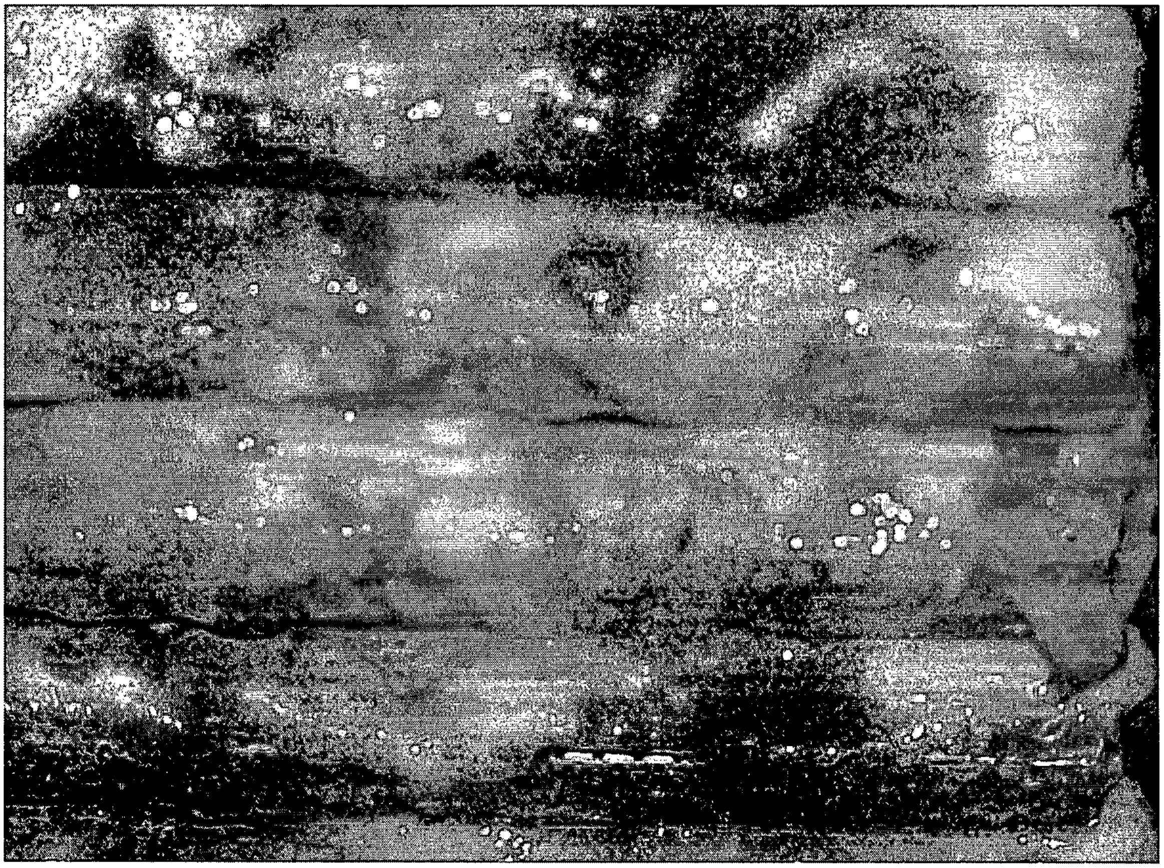


Figure 27-2: Close up of debris laden strainer post test

RAI-28: Provide the test data used to determine the stated exponential extrapolation to the final mission time. State what portion of the head loss data was used to perform the extrapolation. Provide any assumptions used in the evaluation and their bases. Provide sufficient data that a review of the evaluation, test termination criteria, assumptions, and bases can be conducted. Note that the most recent staff guidance (Enclosure 1 of ADAMS Accession No. ML080230112) recognizes linear extrapolation as a conservative extrapolation method.

RAI-28 RESPONSE: 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 / To, 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 Eq. (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, Eq.(2) gives the clean strainer head loss (equal to C1) and as t approaches infinity, ΔH approaches a constant value (C1 + C2). Eq. (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.

Raw data is provided to the NRC staff under separate cover. Headloss data after the last injection of chemicals was used in the extrapolation.

RAI-29: Show that the head loss cases presented at 210°F are the limiting cases for NPSH margin and that lower temperatures do not result in more limiting conditions.

RAI-29 RESPONSE: The 210°F design temperature specified for the St. Lucie Unit 2 ECCS suction strainer design was selected in advance of strainer design based on the assumption that it would be close to the point of minimum NPSH margin prior to the final suction strainer design evaluation and NPSH analyses. 210°F is based on saturation temperature of water at one atmosphere with some margin. It was anticipated that as temperature drops further from 210°F toward 80°F, reduction in water vapor pressure would overcome increased head loss due to viscous effects. Head losses and NPSH calculation results were presented at 210°F in our supplemental response at the strainer design temperature rather than minimum NPSH margin point of 207.9°F. However, the design temperature of 210°F is very close to the minimum NPSH margin point temperature of 207.9°F.

Subsequent to strainer design and installation, detailed temperature dependent head loss NPSH calculations were performed for St. Lucie Unit 2 ECCS pumps for the three limiting flow cases for the recirculation mode following LBLOCA.

For the CSS pumps, Table 29-1 presents the NPSH margin calculation results as a function of temperature for the three flow cases:

Table 29-1

CSS NPSH Case 1A: Design Basis Case			CSS NPSH Case 3: LPSI Failure to Stop Balanced			CSS NPSH Case 5: LPSI Failure to Stop Unbalanced	
T_{sump} [°F]	Approximate NPSH Margin [ft]		T_{sump} [°F]	Approximate NPSH Margin [ft]		T_{sump} [°F]	Approximate NPSH Margin [ft]
80	32.7		80	34.2		80	28.0
90	33.1		90	34.5		90	28.2
100	33.4		100	34.6		100	28.4
110	33.5		110	34.5		110	28.3
120	33.3		120	34.2		120	28.0
130	32.3		130	33.2		130	27.0
140	30.9		140	31.7		140	25.5
150	29.1		150	29.9		150	23.7
160	26.9		160	27.6		160	21.4
170	24.1		170	24.8		170	18.5
180	20.6		180	21.2		180	15.0
190	15.8		190	16.4		190	10.2
200	11.3		200	11.8		200	5.6
207.9	6.4		207.9	6.9		207.9	0.7
210	6.4		210	6.9		210	0.7
220	6.5		220	7.0		220	0.8
230	6.5		230	7.0		230	0.8
240	6.6		240	7.0		240	0.8

For the HPSI pumps, Table 29-2 presents the NPSH margin calculation results as a function of temperature for the three flow cases:

Table 29-2

HPSI NPSH Case 1A: Design Basis Case		HPSI NPSH Case 3: LPSI Failure to Stop Balanced		HPSI NPSH Case 5: LPSI Failure to Stop Unbalanced	
T_{sump} [°F]	Approximate NPSH Margin [ft]	T_{sump} [°F]	Approximate NPSH Margin [ft]	T_{sump} [°F]	Approximate NPSH Margin [ft]
80	26.8	80	28.3	80	29.9
90	27.3	90	28.6	90	30.2
100	27.6	100	28.7	100	30.3
110	27.6	110	28.7	110	30.3
120	27.4	120	28.4	120	30.0
130	26.4	130	27.3	130	28.9
140	25.1	140	25.9	140	27.5
150	23.3	150	24.1	150	25.6
160	21.1	160	21.8	160	23.4
170	18.3	170	18.9	170	20.5
180	14.8	180	15.4	180	17.0
190	10.0	190	10.6	190	12.1
200	5.4	200	6.0	200	7.6
207.9	0.6	207.9	1.1	207.9	2.7
210	0.6	210	1.1	210	2.7
220	0.6	220	1.1	220	2.7
230	0.7	230	1.2	230	2.7
240	0.7	240	1.2	240	2.8

Note from the NPSH margin columns that the temperature of minimum NPSH margin, 207.9°F, is very close to the original 210°F design temperature.

The tables show a significant increase in NPSH margin when the temperatures drop from 207.9°F. This is because of the conservative methodology used in the calculations. Containment pressure was set equal to the minimum partial pressure of air in containment or the saturation pressure of the sump water, whichever was greater. The minimum partial pressure of air was determined to be 13.57 psia, based on containment air at the maximum allowed operating temperature of 120°F, the minimum allowed operating pressure of -0.368 psig, and fully saturated. Note from the tables that the partial pressure of air was not increased as temperature increased above 120°F to 207.9°F, but was decreased as temperatures decreased below 120°F. At 207.9°F the vapor pressure equals 13.57 psi. As temperatures are decreased below 207.9° the minimum partial air pressure is greater than the vapor pressure of the sump water. Therefore, there is an increase in NPSH margin. The conservative methodology shows that NPSH margin actually increases as the temperature decreases.

During a review of the containment water level calculation, a discrepancy was identified with respect to the amount of water vapor suspended in the post LOCA containment atmosphere. The potential impact on the containment pool level is on the order of 1.3 inches and does not significantly impact sump strainer performance. This issue has been entered into the corrective action program.

RAI-30: Provide an evaluation of flashing across or within the strainer. If the head loss across the strainer can exceed the submergence, provide an evaluation of the physical phenomena that prevent flashing. Provide the margins available to prevent flashing.

RAI-30 RESPONSE: FPL has performed a flashing analysis which determines the margin to flashing across the sump screens for two different flow cases for St. Lucie Unit 2. The first is for the LPSI pump failure to trip on RAS case with a clean strainer. St. Lucie Unit 2 EOPs require operators to manually stop the LPSI pump upon failure to automatically stop on RAS. FPL has evaluated this response and concluded that the mandated operator action can be accomplished before significant head loss due to strainer debris buildup materializes during the recirculation mode. This case is based on a flow of 8470 gpm across a clean strainer. The lowest margin analyzed is at the lowest temperature considered of 65 °F. The margin to flashing for this case is greater than 25 ft.

The second case is for the design basis flow and debris laden strainer head loss for a flow of 4970 gpm. The lowest margin analyzed is at the lowest temperature considered of 65 °F. The margin to flashing for this case is greater than 20 ft.

The submergence for a SBLOCA is 0.52 feet less than the LBLOCA. The margin in feet of water may be reduced by 0.52 foot for a SBLOCA.

Assumptions used for the evaluation include:

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 LBLOCA 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 LBLOCA and the water from the RWT pumped into containment during the injection phase. The water from the RWT is at a much lower temperature than the water created by the LBLOCA. 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 LBLOCA 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 LBLOCA containment pool temperature is conservatively assumed to be equal to containment atmosphere temperature.

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

8 Flow rates through the ECCS/CSS suction strainer debris bed are laminar with associated head losses varying with kinematic viscosity. The kinematic viscosity is the dynamic viscosity divided by the density.

The partial pressure of air already in containment was credited to prevent flashing. The partial pressure of air was determined using the most conservative assumptions. Based on the assumption that the water in the sump is at saturation, the minimum partial air pressure was calculated. The normal atmospheric pressure outside containment is assumed to be 14.7 psia. The minimum allowable containment pressure is -0.368 psig. The maximum operating temperature in containment is 120°F. The vapor pressure of water at 120°F is 1.69 psia. Therefore, the minimum partial pressure of air in containment is 14.7 psia – 0.368 psi – 1.69 psi = 12.642 psia when the temperature in containment is 120°F. The partial pressure of air was then adjusted according to temperature over an entire range from 65°F to 240°F. Note that it is not even necessary to credit air heating to achieve significant margins.

RAI-31: On page 34, the supplemental response describes an accordion divider plate with 1/16-inch holes being installed in the suction plenum to prevent debris from transporting from one half of the strainer to the opposite suction line. This opening size is the same as the openings in the perforated plate. This strainer design is similar to independent strainers in that, for the case of a failure of a single train, much of the debris will be accumulated only on one half of the strainer surface if the limited surface area divider plate were to become blocked. Even during the design basis, non-single failure case, there will be a flow asymmetry due to one CSS train being shut down. That is, a steady-state flow across the divider plate will be present. If blockage occurs across this divider plate, the clean strainer and debris bed head losses will be greater than those calculated assuming no divider plate blockage. Based on these considerations, demonstrate either that blockage will not occur at the divider plate, or, if blockage at the divider plate can occur, demonstrate that the current St. Lucie Unit 2 head loss testing results bound this condition. Separately, provide the surface area of the divider plate.

RAI-31 RESPONSE: The St. Lucie Unit 2 strainer system design does not consider independent function of the strainers and does not postulate a passive failure. Blockage across the divider plate is not part of the strainer design basis.

Design Bases for Containment Sump Screens

"The two containment spray pump recirculation intake pipes take suction from a common containment emergency sump. The sump is partitioned to provide for separation of the suction piping and is enclosed by a screen assembly to prevent the entry of debris that could clog the spray nozzles. The protective screen assembly design is consistent with the guidelines of Regulatory Guide 1.82, "Sumps for Emergency Core Cooling and Containment Spray System," and is acceptable."

The accordion divider plate has been included in the new St. Lucie Unit 2 strainer design to maintain consistency with the original NRC approved partitioning.

The St. Lucie Unit 2 sump design does not utilize redundant and spatially separated sumps, each with its own filtering screen. There is a single common sump with both ECCS/CSS recirculation suction lines within it. However, this common sump is spatially separated from those areas within containment that would be subjected to jet impingement and pipe whipping during a LOCA event by the massive SBS wall. This location, outside the bio-shield, ensures that the containment sump is well protected from missiles, steam jets, water jets, pipe whip, large debris, etc., that could possibly occur in the event of a design basis accident. While use of a single common sump does not meet the recommendations of Reg. Guide 1.82 for redundant sumps, the physical protection of this common sump by its location outside the bio-shield certainly meets the Reg. Guide recommendations for separation of the sump by structural barriers from whipping pipes and high velocity steam or water jets. The use of a common sump in lieu of redundant and physically separated sumps was reviewed and approved by the NRC during the plant licensing period. The physical separation of the common sump from those areas of containment that are exposed to severe LOCA accident conditions was sufficiently robust for the NRC reviewers to conclude that the design met the intent of Reg. Guide 1.82.

Single-Failure and Redundancy

The previously existing containment sump screens were not required to be designed as a redundant or single-failure proof component. The ECCS design basis considers an active component failure or a limited leakage failure of a passive component and the CSS design basis only considers a failure of a single active component.

The strainer modules and plenum are designed as Seismic Class I equipment. All required load combinations have been shown to be acceptable, including crush pressure. Additionally, environmental conditions and dynamic effects associated with a LOCA have been considered and will not result in the failure of the strainer system. Finally, using the mechanistically determined, conservative maximum hypothetical debris loading, the strainer system has been demonstrated by testing that adequate NPSH will be available to the ECCS/CSS pumps during all phases of recirculation.

Therefore, the strainer system is designed to preclude credible sources of passive failure, and is not designed as a redundant or single-failure proof system. This is consistent with the previous design and licensing basis of the system.

GL 2004-02 does not impose requirements with regards to redundancy or separation. The plenum of the new strainer is divided between strainer modules 4 and 5 by an accordion section of 1/16" perforated plate. This division of the plenum meets the design requirements of the common strainer for St. Lucie Unit 2 since it segregates the common strainer, allows flow between the two halves of the strainer and will not allow passage of particles greater than 0.135" in diameter. The divider plate will not clog since the strainer modules prevent passage of particles with diameter greater that 0.06875" in diameter.

The new St. Lucie Unit 2 strainer system has no active components and does not affect the design of any existing active components. Accordingly, only passive failure modes apply to the equipment added by this modification. The strainer system installed consists of a single, shared strainer system for both CSS/ECCS trains. Therefore, credible failure modes are precluded by the design, rather than tolerated by redundant systems. The following failure modes were considered in the design:

Structural Failure

A major structural failure would result in loss of debris retention and failure of both recirculation trains due to debris intrusion. The strainer modules and all associated piping are designed as Seismic Class I components, which precludes credible structural failure under postulated loading conditions. This includes a specified crush pressure that exceeds the calculated head loss postulated for the sump strainers.

Damage by high energy line break (HELB) and Environmental Conditions

Damage to the strainers and associated equipment by HELB effects or environmental conditions would result in failure of both recirculation trains due to debris intrusion. The strainer system has been analyzed for possible HELB forces and found to be acceptable. The strainer system design considers the normal and post-accident environmental conditions to which it could be subjected. It is not subject to corrosion or failure under the temperature, pressure, or chemical conditions to which it would be exposed.

Debris Bypass

Debris not captured by the strainer system may enter the recirculation systems, potentially causing blockage or excessive wear of recirculation components. Debris inside of the strainers or piping will be prevented by appropriate station foreign material exclusion practices when any part of the strainer system is disassembled (Modes 5 and 6, only).

Fabrication or installation deficiencies could potentially result in debris pass-through larger than expected. The strainers and associated equipment are designed to retain 100% of debris larger than 0.06875 (+0) in. (~1/16 in.). The equipment procured and installed at St. Lucie Unit 2 is done so under FPL-approved vendor QA programs that assure that the specified debris retention capabilities are met.

Excessive Head Loss

The strainer system must be capable of providing sufficient $NPSH_A$ to the ECCS/CSS pumps during recirculation to prevent pump cavitation. Excessive debris build-up or larger-than-anticipated head loss could result in failure of both ECCS/CSS trains. The new strainer system is designed to retain a mechanistically determined debris load for the most severe LOCA in containment while providing adequate $NPSH_A$ to the ECCS/CSS pumps. The GL 2004-02 methodology used to develop the debris load is inherently conservative. Therefore, this is not a credible failure mode.

In conclusion, the strainer system is not a redundant configuration, which is consistent with the previous design. The equipment installed by this modification is passive, and does not affect any existing active components. Therefore, the strainers and associated equipment have been designed to preclude all credible modes of passive failure and are acceptable with regards to failure modes and effects analysis (FMEA).

The plenum divider consists of nine perforated plate covered strainer plates 11 ½ by 16 inches or approximately 11.5 sq ft.

RAI-32: Provide technical justification in support of the assumption of "no blockage of the refueling pool canal drains." Identify the type, physical characteristics (size, shape, etc.), and amounts of debris which may be blown into the refueling cavity during a LOCA. If it is determined that drainage from the refueling cavity could be blocked, specify the volume of water held up in the cavity and state the effect on minimum containment sump pool level.

RAI-32 RESPONSE: The St. Lucie Unit 2 refueling cavity pool canal drains consist of two redundant six (6) inch diameter drains located on the side of the cavity wall with centerlines six inches from the cavity bottom, approximately 3 feet apart.

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 SBS wall through the floor at elevation 62 ft. and into the refueling cavity and outside the SBS wall. The limiting St. Lucie Unit 2 breaks are within the SBS wall around the RCS loop level. These reviews concluded that pathways from the loop break area up and through the 62 ft level floor were few and torturous to the point of being inconsequential for any type of debris considered. This is due to large solid floor area at elevation 62 ft, relatively small compartment areas covered with grating, and tight clearances around stairs, curbs and penetrations.

No significant pathway was found to exist through the SBS wall at the lower wall drain widows which are blocked with trash racks.

FPL analysis has not quantified the type, physical characteristics (size, shape, etc.), and amounts of debris which may be blown into the refueling cavity during a LOCA. But, if you assume that significant debris is able to make its way vertically over 40 feet against the forces of gravity and falling containment spray flow and through the aforementioned tortuous path, the following design features preclude total blockage of both drain paths:

- Drains are redundant.
- Drains are separated.
- Drains are horizontal and wall located rather than vertical and floor located to minimize gravity effects on debris transport.
- Drains are submerged at post LOCA recirculation mode containment level, thereby minimizing wash down/transfer velocity of containment spray to the drains. Any postulated floating debris is prevented direct access to drain penetrations since the post LOCA surface is greater than the centerline of the 6 inch drains is at El. 22'-0". This provides more than one foot of fluid flotation between the water surface and the top of the drains.
- Drain diameters are large 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.
- Design drawings indicate no protective screens at the drains to become obstructed with smaller debris that would otherwise pass through the drain or accumulate on the cavity floor.

- Drains are above the cavity floor so that significant debris can be accumulated in the "heel" of the cavity before reaching drain level.

Therefore, the fuel transfer canal drains do not create a chokepoint at St. Lucie Unit 2.

RAI-33: The NRC staff considers in-vessel downstream effects to not be fully addressed at St. Lucie Unit 2 as well as at other PWRs. Florida Power & Light Company's submittal 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 St. Lucie Unit 2 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 St. Lucie Unit 2. 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 Generic Safety Issue 191.

RAI-33 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 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 St. Lucie Unit 2 in-vessel downstream effects will be bounded by the final version of WCAP-16793-NP. Also, at this time, FPL believes that St. Lucie Unit 2 will be in compliance with the NRC's safety evaluation (SE) of the final WCAP-16793-NP.

In FPL's June 30, 2008 supplemental response on Generic Letter 2004-02, the response to Topic 3.n stated that St. Lucie Unit 2 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, St. Lucie Unit 2 performed a unit specific analysis for chemical plate out on the fuel that yielded satisfactory results for fuel temperatures of only 361.5 ^{o}F. In the June 30, 2008 supplemental response, Attachment 4, Enclosure 2, FPL also provided St. Lucie Unit 2 responses to NRC staff's Limits and Conditions related to the staff's initial review of WCAP 16793-NP.

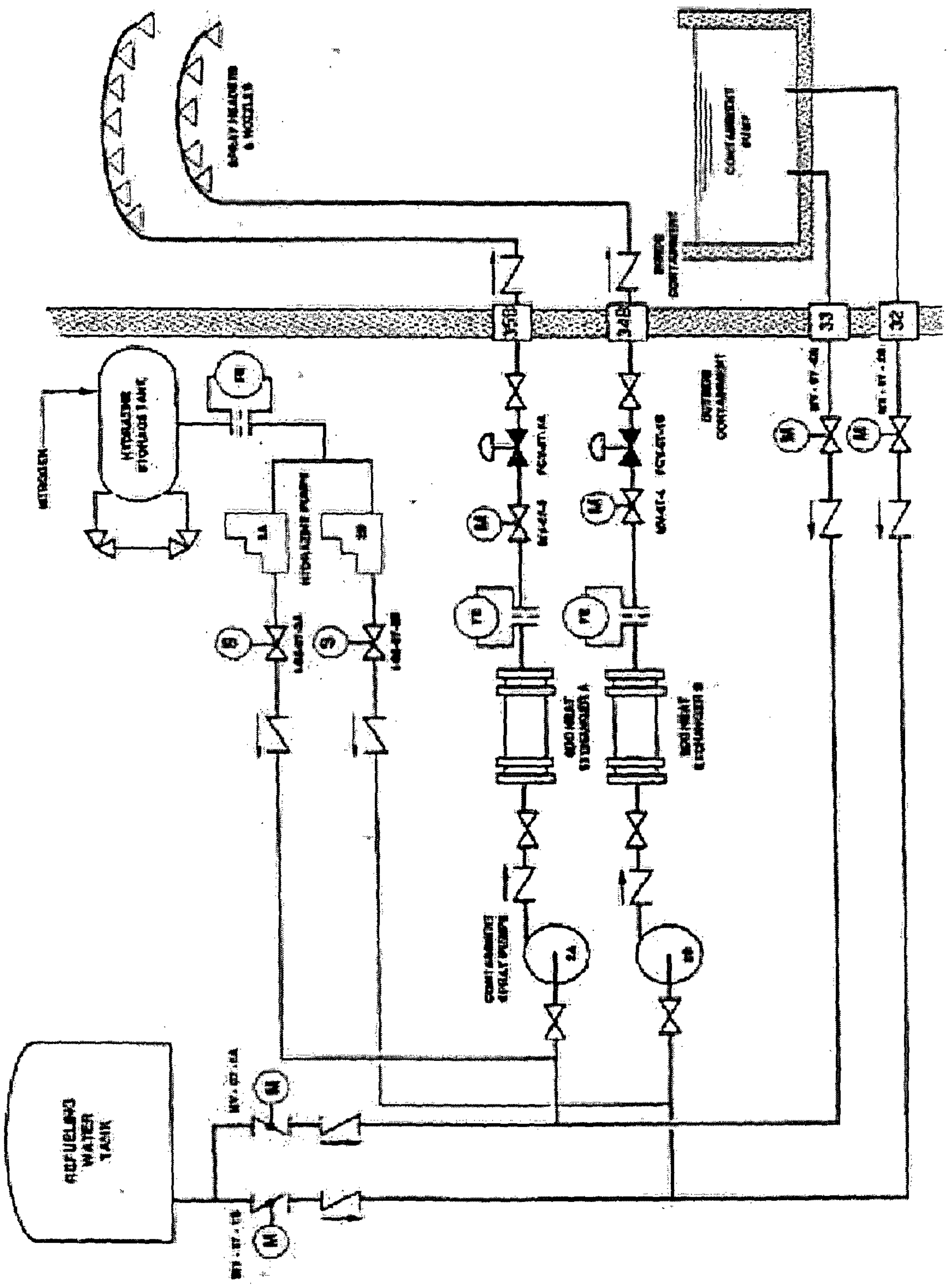
FPL believes that sufficient evaluation has been conducted for St. Lucie Unit 2 to demonstrate acceptable in-vessel conditions. However, at the recent joint NEI/NRC meeting on January 14 and 15, 2009, NRC requested industry assurance that plants will submit a final in-vessel evaluation within 90 days after NRC issues a 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-34: Provide a description for the item in Table 3.g-3: "NaH_4" storage tank.

RAI-34 RESPONSE : The NaH4 (hydrazine) storage tank is part of the St. Lucie Unit 2 iodine removal system (IRS) as shown in the schematic diagram below. The minimum tank volume consists of 675 gallons of useable volume. This useable volume is calculated after accounting for the unusable volume below the 2" low-low set point and instrument inaccuracies. The above assumptions result in the Technical Specification requirement of 675 gallons.

The iodine removal system provides hydrazine to enhance the containment spray systems ability to remove airborne fission products from the containment atmosphere following a LOCA or CEA ejection event. The system is designed to withstand a single active component failure coincident with a loss of off-site power (LOOP).

SIMPLIFIED DIAGRAM OF THE CONTAINMENT SPRAY AND IODINE REMOVAL SYSTEMS



RAI-35a: Provide more details concerning the plant-specific integrated head loss testing at ALDEN Labs including the following:

A Plot of the pressure drop as a function of time that also shows when debris and chemical precipitates were added to the test flume.

RAI-35a RESPONSE: A plot of head loss versus time was not completed while developing the St. Lucie Unit 2 Strainer Test. The graph presented below was developed for this RAI based on the raw data contained in the St. Lucie Unit 2 Strainer Test Plan. See Figure 35a-1, head loss versus time (test hours) plot below.

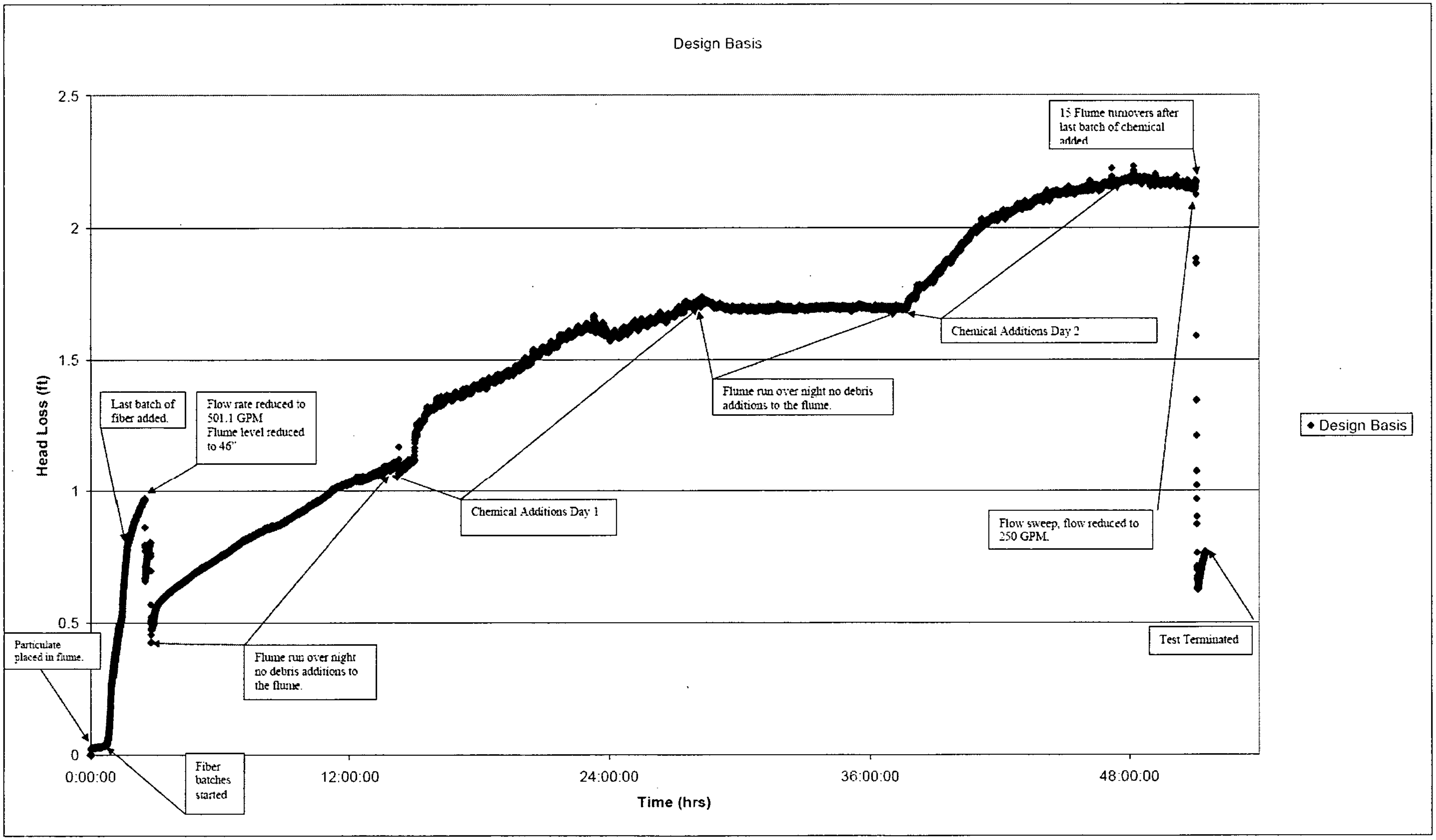


Figure 35a-1: Head Loss Versus Time for PSL2

RAI-35b: Provide more details concerning the plant-specific integrated head loss testing at ALDEN Labs including the following:
A discussion of how the integrated head loss test results were extrapolated to 30 days.

RAI-35b RESPONSE: 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 / To, 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 Eq. (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, Eq. (2) gives the clean strainer head loss (equal to C1) and as t approaches infinity, ΔH approaches a constant value (C1 + C2). Eq. (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.

RAI-35c: Provide more details concerning the plant-specific integrated head loss testing at ALDEN Labs including the following:

Photographs showing the strainer test section and flume after test completion.

RAI-35c RESPONSE: The photographs below (Figures 35c-1 through 35c-6) are contained in St. Lucie Unit 2 Strainer Test Report. Figures 35c-7 and 35c-8 are extra photographs taken during the documentation process.

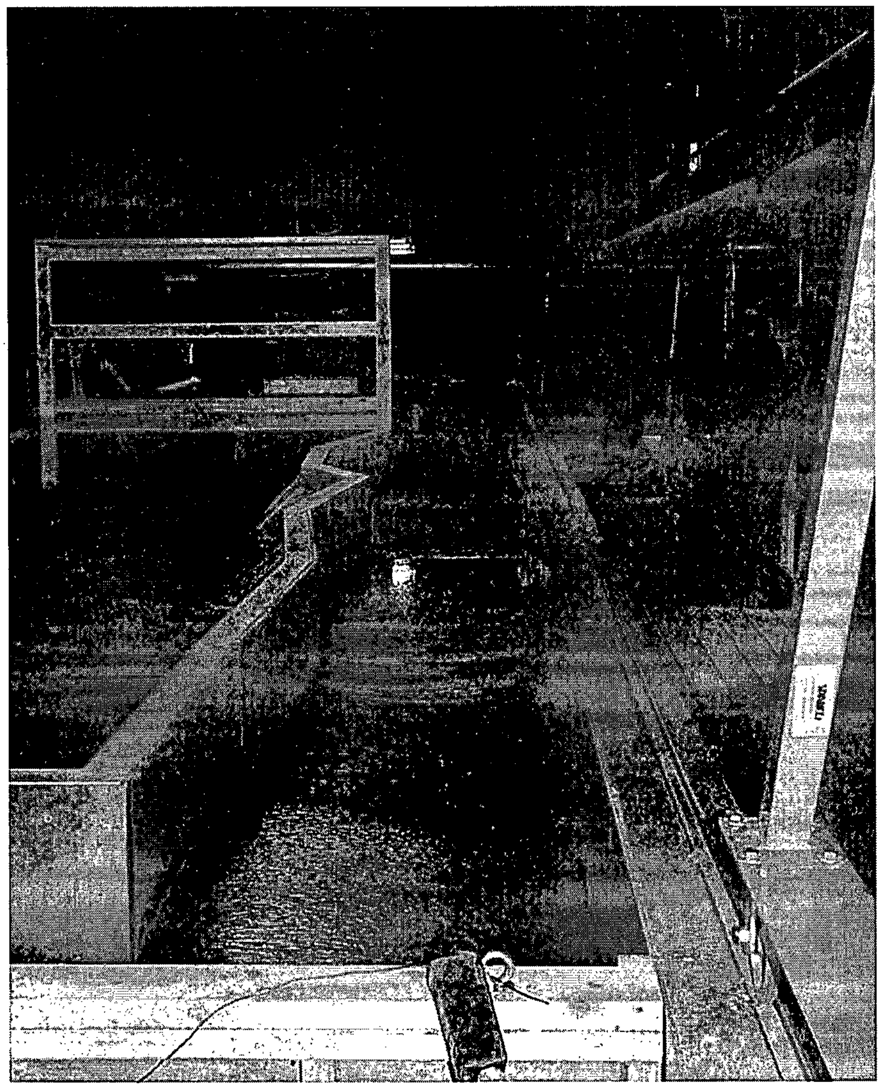


Figure 35c-1: Floating Debris Upstream of Strainer at Test

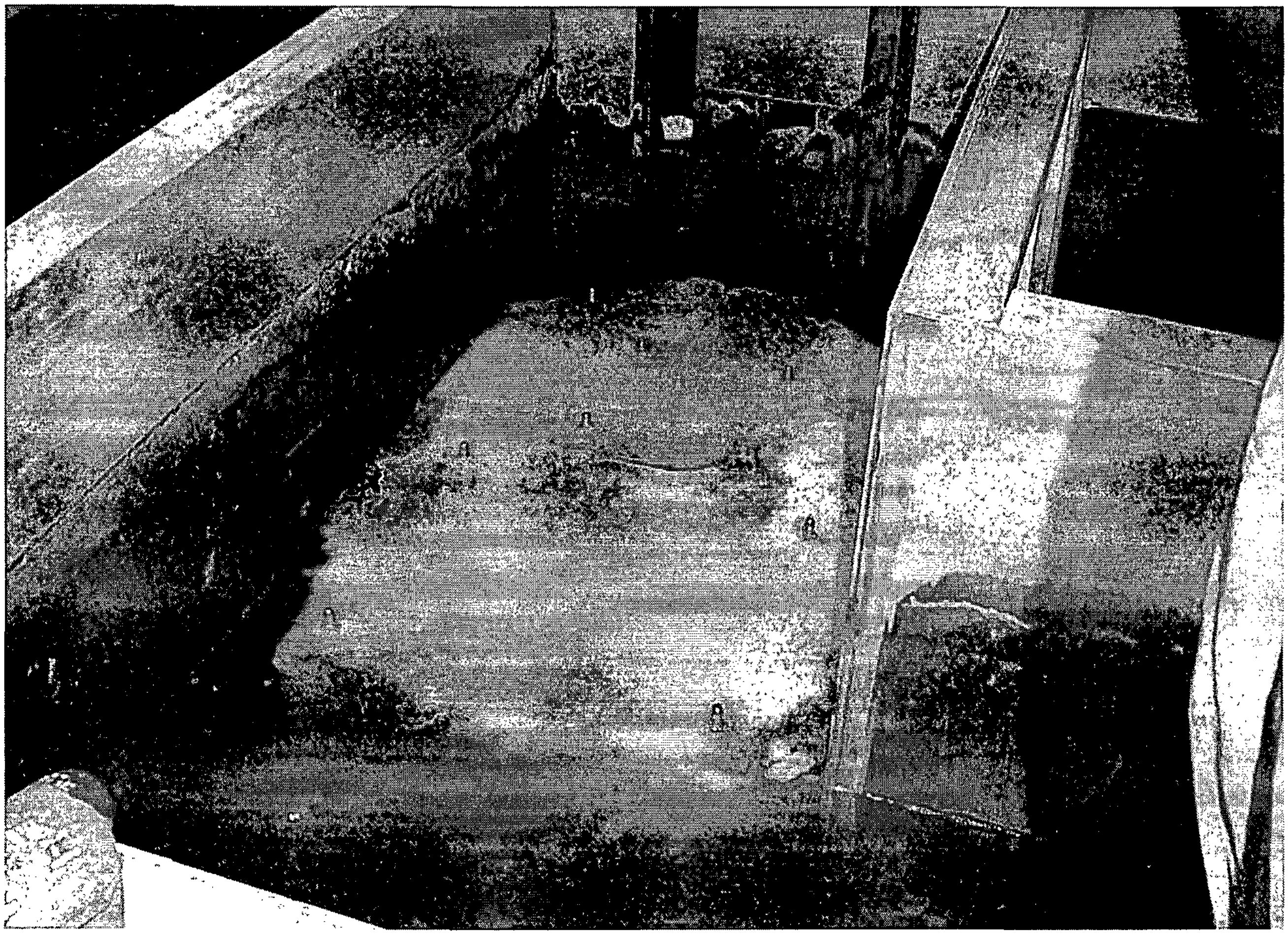


Figure 35c-2: Strainer During Drain Down

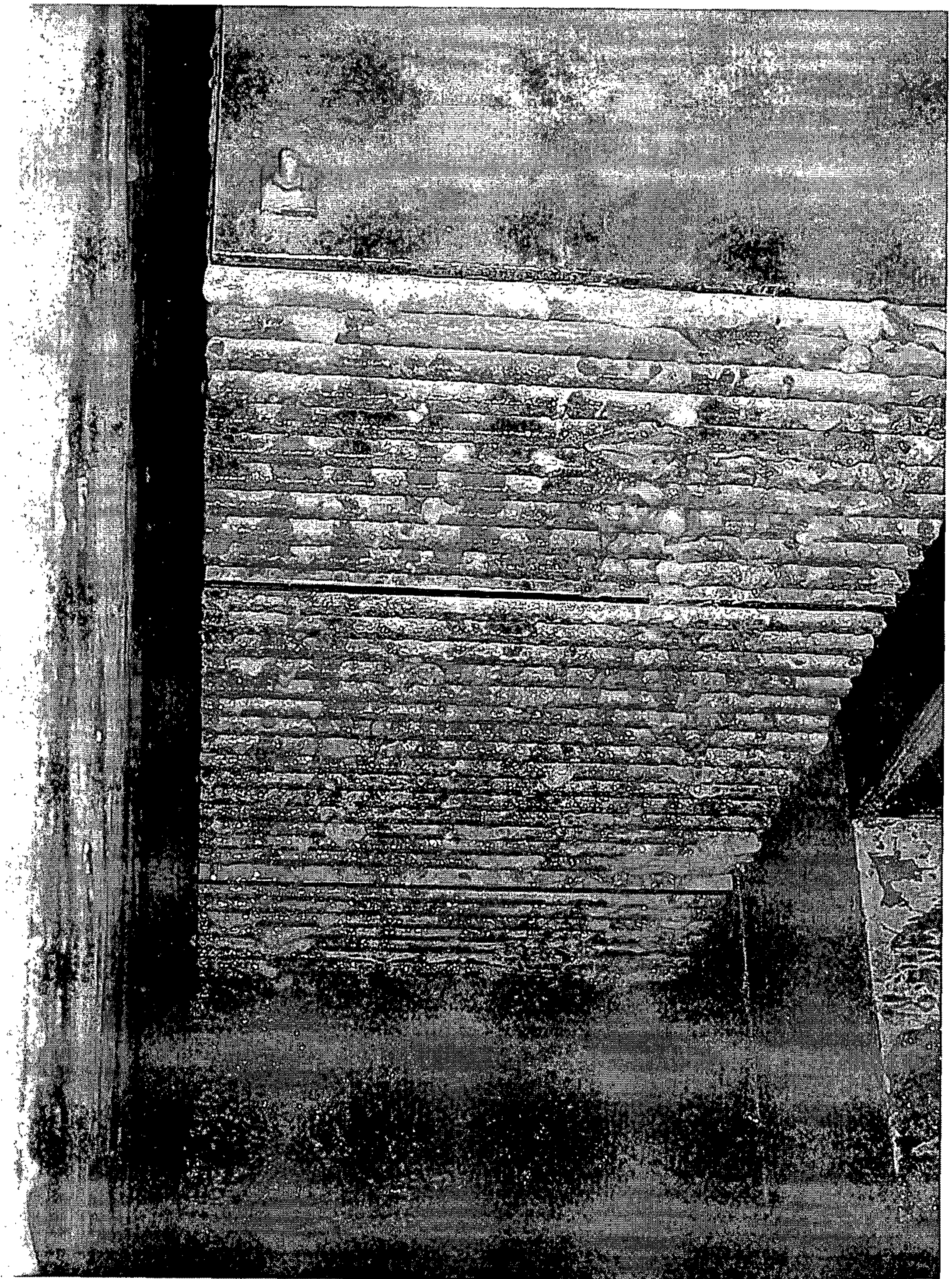


Figure 35c-3: Design Basis Debris Laden Strainer

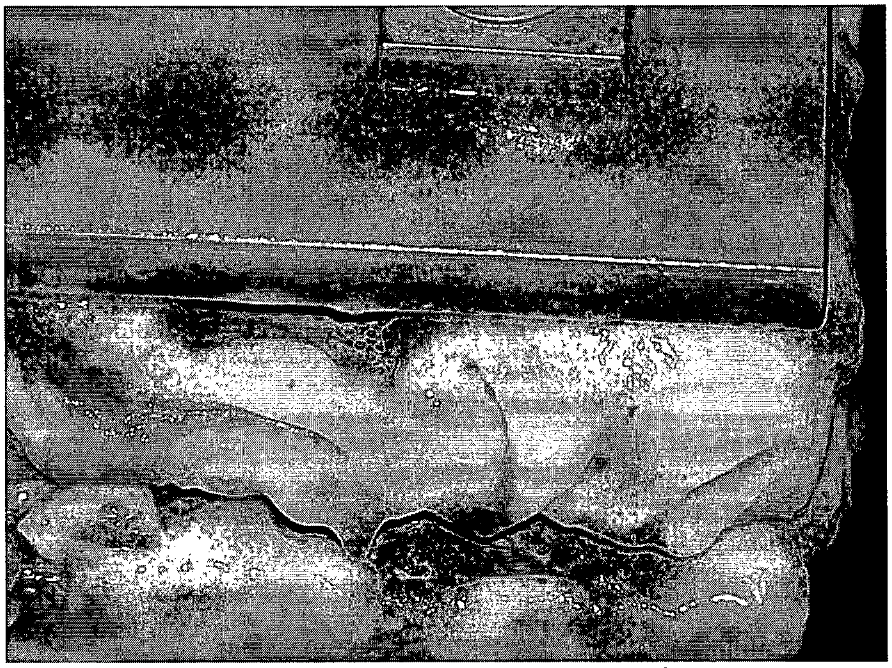


Figure 35c-4: Close up of Debris Laden Strainer

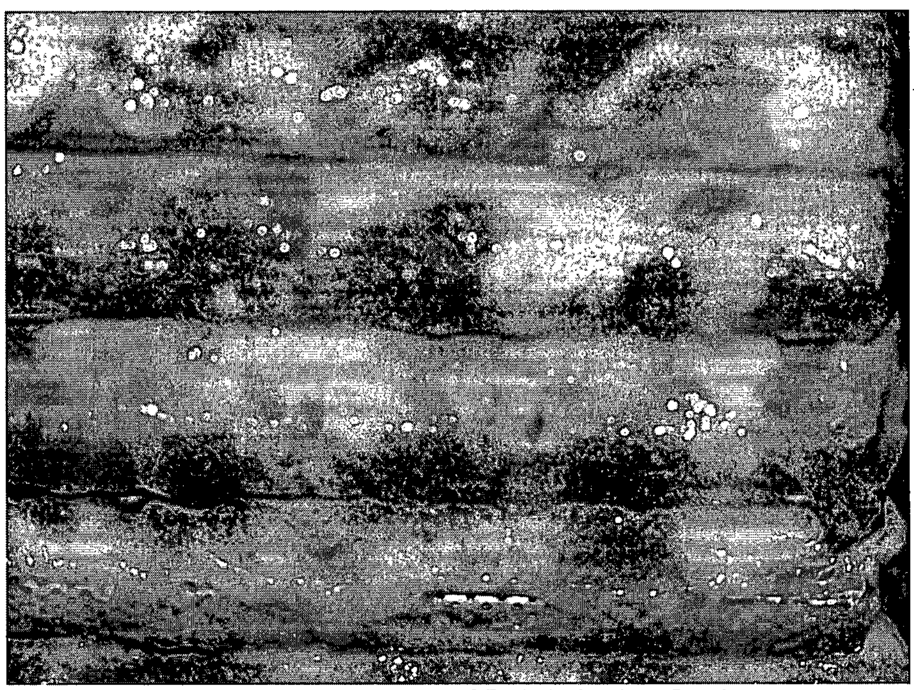


Figure 35c-5: Close up of Debris Laden Strainer

Figure 35c-6: Non Transported Debris Upstream of Strainer post Design Basis Test Looking Towards strainer

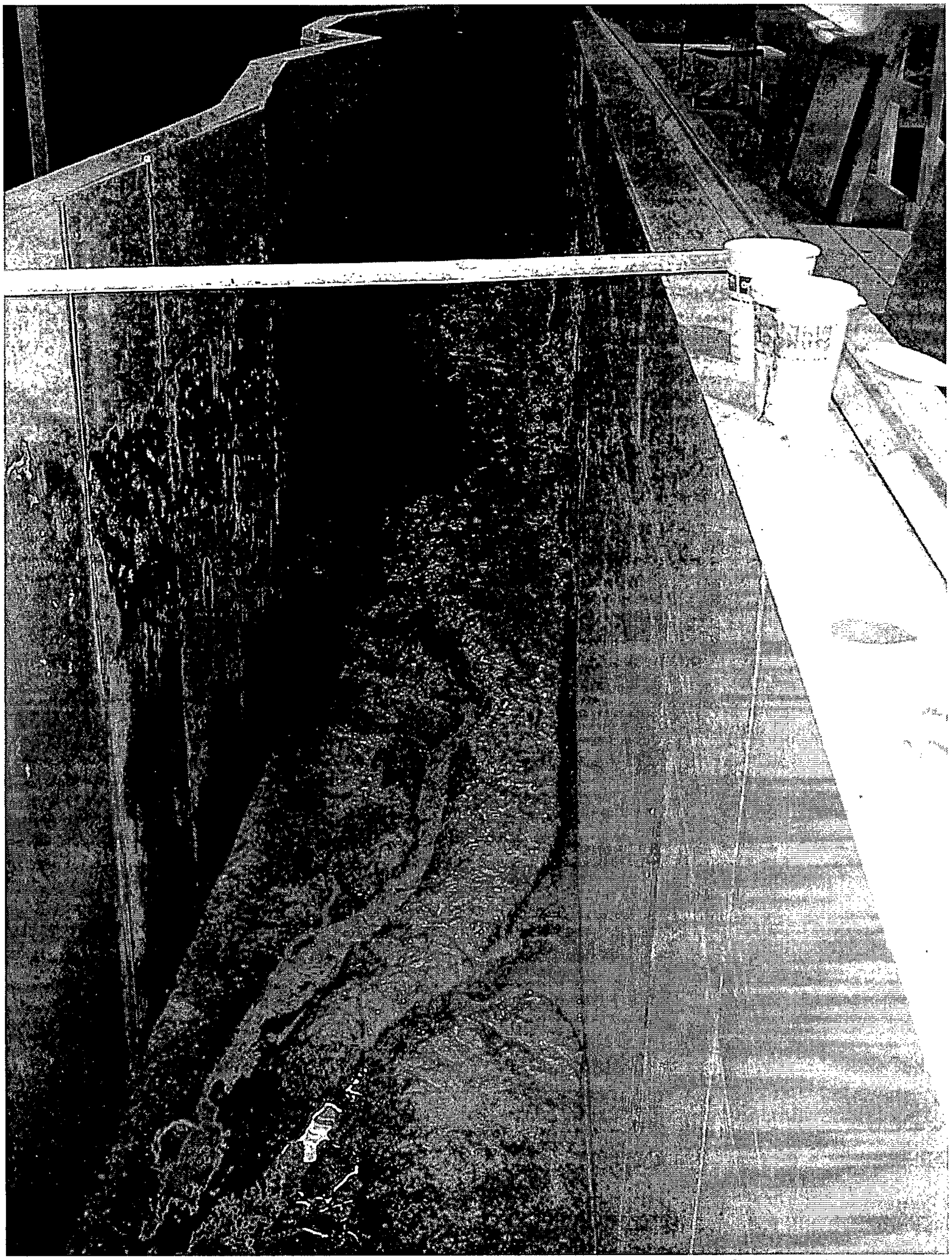


Figure 35c-7: Debris in flume after drain down looking away from strainer

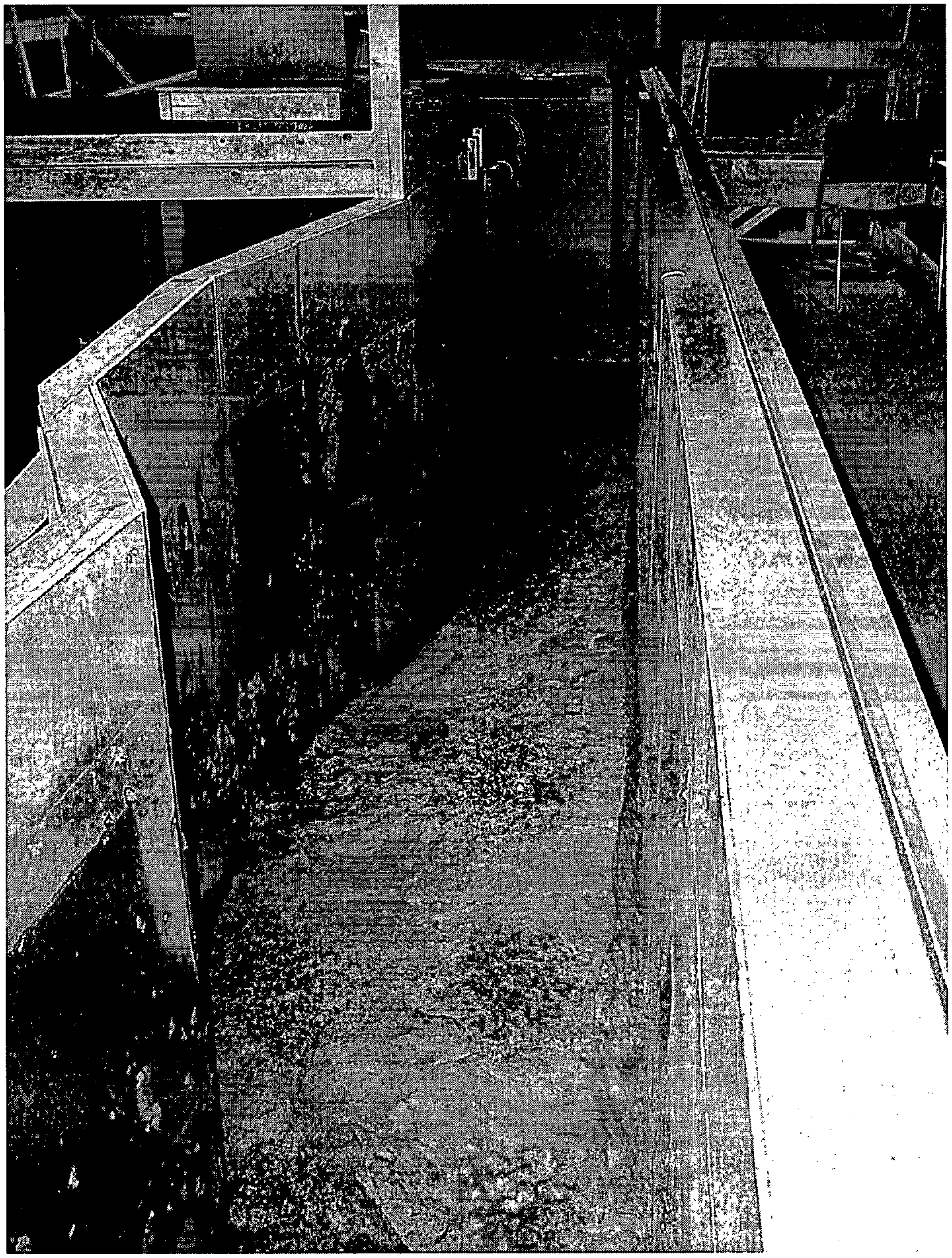


Figure 35c-8: Debris Downstream of the Drop Zone

RAI-35d: Provide more details concerning the plant-specific integrated head loss testing at ALDEN Labs including the following:

An estimate of the percentages of materials that settled in the flume upstream of the test strainer.

RAI-35d RESPONSE: The amount of debris that settled due to near term settling was not collected and dried to determine the amount of debris that settled due to near-field settling. The industry guidance provided in NEI 04-07 did not require that an estimate, determination or calculation of the percentages of materials that settled in the flume upstream of the test strainer. Figure 35d-1 below depicts the debris that settled out due to near term settling.

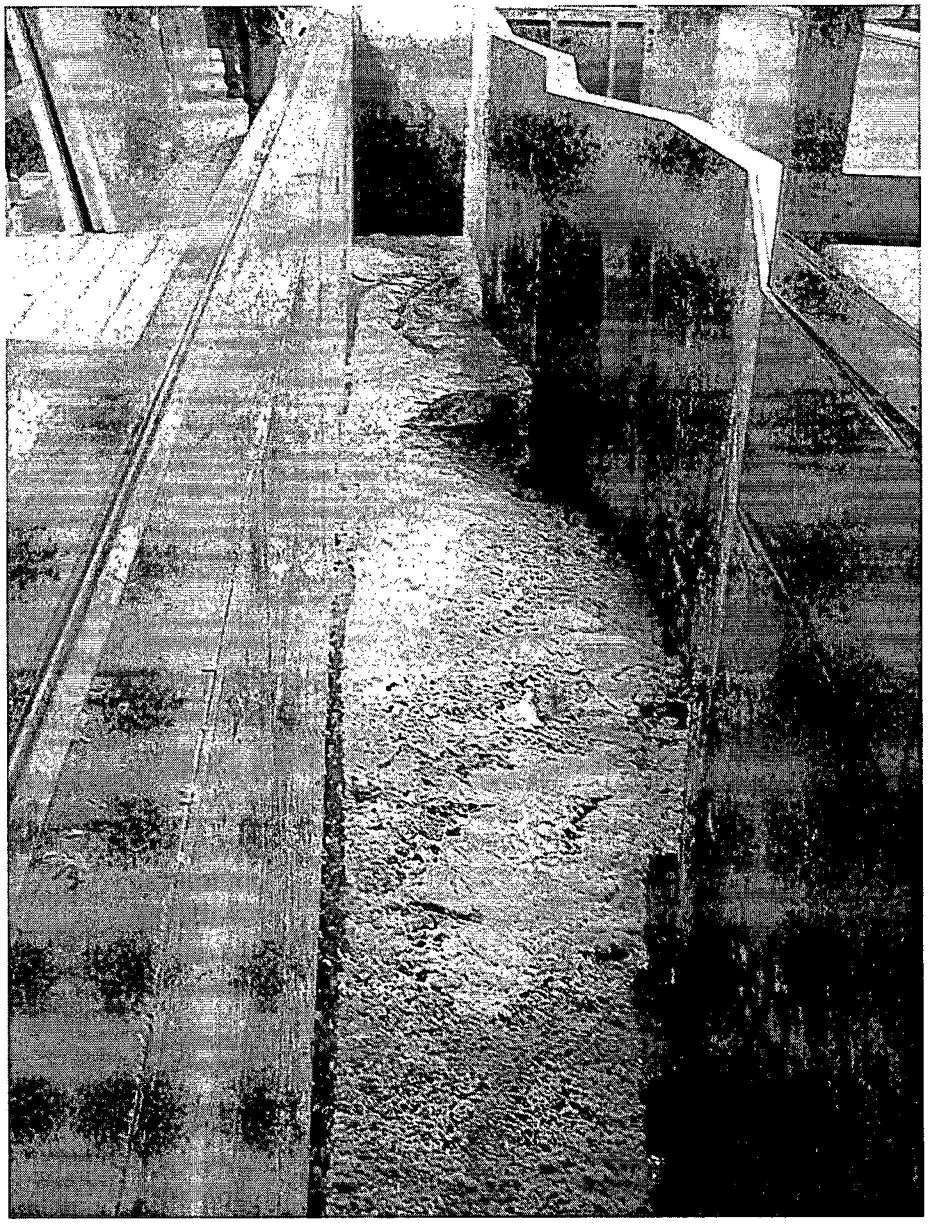


Figure 35d-1: Debris in test flume post test

RAI-36: State whether FOAMGLAS® insulation material, if floating in the containment pool, leaches any chemicals that need to be considered as part of the chemical effects analysis. If so, please describe the chemicals leached and estimate the quantities of these chemicals as a function of time.

RAI-36 RESPONSE: Design documents show the FOAMGLAS® insulation installed on several component cooling water lines supplying the reactor coolant pumps. This is anti sweat insulation made of glass manufactured by the Pittsburgh Corning company. This single application represents a very small fraction of the total amount of insulation debris generated within the containment building for the limiting break.

The Pittsburgh Corning company web site lists physical and thermal properties of FOAMGLAS®. The OEM product technical mechanical specification data sheets indicate the density to be approximately 7.5 lb per cu. ft. This is somewhat higher than the density taken for fiberglass blanket insulation (4 lb per cu ft.) but within the same range.

The Pittsburgh Corning technical product data sheet also states that FOAMGLAS® is non combustible, is impervious to common acids (hydrofluoric excepted), is composed of pure glass, is totally inorganic, and contains no binder.

The total amount of FOAMGLAS® postulated to be generated, even during the limiting break, is very small compared to the overall debris load (18.05 cu. ft.). This is due to the very small amount installed in containment for the anti sweat protection application. Even if chemicals were leached from FOAMGLAS®, they would represent a very small amount of debris deposited into the containment pool. Additionally, if FOAMGLAS® were floating in the containment pool, even less of the surface area of the small amount of generated FOAMGLAS® would be exposed to possible leaching effects in the liquid pool.

Therefore, it was concluded that FOAMGLAS® does not contain significant leachable chemicals that need to be considered for the chemical effects analysis. Accordingly, leachable chemicals from FOAMGLAS® were not considered in the St. Lucie Unit 2 chemical effects analysis.