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Nuclear LLC

10 CFR 50.54(f)

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April 22, 2013

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
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Salem Generating Station, Units 1 and 2
Renewed Facility Operating License Nos. DPR-70 and DPR-75
NRC Docket Nos. 50-272 and 50-311

Subject: Final Responses to NRC Questions Regarding Salem Bypass Testing

References:

(1) NRC Generic Letter 2004-02: Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors, dated September 13, 2004, ADAMS Accession No. ML042360586
(2) PSEG letter LR-N12-0124, Final Supplemental Response to Generic Letter 2004-02, dated April 27, 2012, ADAMS Accession No. ML121290536
(3) Summary of November 28, 2012, Public Conference Call with PSEG Re: Final Supplemental Response to Generic Letter 2004-02 For Salem Nuclear Generating Station, Units 1 and 2, dated January 30, 2013, ADAMS Accession No. ML13010A325
(4) Summary of February 28, 2013, Public Meeting with PSEG Re: Final Supplemental Response to Generic Letter 2004-02 for Salem Generating Station, Units 1 and 2, dated April 5, 2013, ADAMS Accession No. ML13078A448

On September 13, 2004, the NRC issued the Reference 1 letter, Generic Letter (GL) 2004-02. GL 2004-02 requested that each plant perform an evaluation of the Emergency Core Cooling System and Containment Spray System recirculation functions in light of the information provided in the Generic Letter, and, if appropriate, take additional actions to ensure system function.

PSEG Nuclear LLC (PSEG) provided a number of responses to GL 2004-02, including a final supplemental response on April 27, 2012 (Reference 2). The NRC staff provided feedback to PSEG on the final supplemental response, including 18 questions regarding Bypass Testing, during a public conference call on November 28, 2012 (summarized in Reference 3).

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PSEG and the NRC staff discussed draft responses to the 18 NRC staff questions at a public meeting on February 28, 2013, as summarized in Reference 4. PSEG hereby submits the final responses to the NRC staff questions as Attachment 1 to this letter.

There are no new regulatory commitments contained in this submittal.

If you have any questions or require additional information, please do not hesitate to contact Mrs. Emily Bauer at (856) 339-1023.

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

Executed on 4/22/2013
(Date)

Sincerely,

Carl J. Fricker
Site Vice President – Salem Generating Station

Attachment 1 Responses to NRC Questions Regarding Salem Bypass Testing During Teleconference Held on November 28, 2012

cc: Mr. W. Dean, Administrator, Region I, NRC
Mr. J. Whited, Project Manager, NRC
NRC Senior Resident Inspector, Salem
Mr. P. Mulligan, Manager IV, NJBNE
Mr. L. Marabella, Corporate Commitment Tracking Coordinator
Mr. T. Cachaza, Salem Commitment Tracking Coordinator

Responses to NRC Questions Regarding Salem Bypass Testing During Teleconference Held on November 28, 2012

1) ***The screen used to catch the fiber was 0.31mm or 310 micron. How was it ensured that fiber did not bypass the screen considering that Nukon is 7 micron diameter and many of the bypassed fiber pieces are less than 250 microns in length with almost all less than 500 microns? Any fiber bypassing the screen may have been caught on the strainer on its next pass. Please provide the bypass amounts and debris sizes that would be expected to pass through the strainer and captured on a 100% efficient filter, and the method and assumptions used to calculate these values.***

During both the 2006 and 2008 bypass testing, the fibers which bypassed the strainer were collected on a 0.31 mm stainless steel mesh with a maximum diagonal opening of 0.44 mm.

The bypass fiber size distribution downstream of the strainer and upstream of the fiber bypass capture screen was obtained through grab samples for bypass Test 3a in 2006 and for bypass Tests 1, 2 and 3 in 2008. Based on Bypass Tests 1 and 2 from 2008, which are expected to be the most representative of the actual fiber size distribution that bypasses the strainer, only 26% of the fibers that bypass the strainer are less than 0.5 mm in length (Table 3f.4.2.2.2-2 of 2012 Supplemental Response). However, this percentage is based on a fiber count rather than fiber mass.

The fiber bypass size distribution results are based on a pooled collection of various grab samples taken throughout the test. Specifically, the pooled collection method for 2008 Bypass Tests 1 and 2 utilized samples taken 12, 27, 42, and 57 (Test 2 only) minutes after the initial fiber addition; thus, a fiber bed had formed on the strainer surface prior to taking the grab samples. The interstitial spaces in the fiber bed are smaller than the strainer perforations, resulting in fewer large bypassed fibers than prior to fiber bed formation. Therefore, the size distribution of fibers measured with the grab samples conservatively includes a disproportionate fraction of smaller fibers since a fiber bed formed on the strainer prior to taking the utilized grab samples. Using a fiber size distribution with more small fibers is conservative for this analysis since it results in a higher fiber bypass "bump-up."

The percent of bypassed fibers by mass that are in Size Class 1 (0.1 mm to 0.5 mm in length) in Table 3f.4.2.2.2-2 of the 2012 Supplemental Response is calculated for 2008 Bypass Tests 1 and 2 using the equation below.

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$$M_1 = \frac{P_1 \cdot \rho_f \cdot \frac{\pi \cdot D_1^2}{4} \cdot L_1}{P_1 \cdot \rho_f \cdot \frac{\pi \cdot D_1^2}{4} \cdot L_1 + P_2 \cdot \rho_f \cdot \frac{\pi \cdot D_2^2}{4} \cdot L_2 + P_3 \cdot \rho_f \cdot \frac{\pi \cdot D_3^2}{4} \cdot L_3 + P_4 \cdot \rho_f \cdot \frac{\pi \cdot D_4^2}{4} \cdot L_4}$$

Where: M = percentage of fiber in each size class by mass
L = length of fiber
ρ_f = fiber density
D = fiber diameter
P = percentage of fibers in each size class by count
Subscripts 1, 2, 3, and 4 denote size classes from Table 3f.4.2.2.2-2 of the 2012 Supplemental Response

The fiber density (ρ_f) and fiber diameter (D) are constant across all size classes; therefore, the equation above is reduced to the following:

$$M_1 = \frac{P_1 \cdot L_1}{P_1 \cdot L_1 + P_2 \cdot L_2 + P_3 \cdot L_3 + P_4 \cdot L_4}$$

Values of percentage by count (P) are taken from Table 3f.4.2.2.2-2 of the 2012 Supplemental Response. The average fiber length of each size class is used as the fiber length (L). For Size Class 4 (>1.5mm) an average fiber length of 1.5 mm is used, which conservatively reduces the percentage of fibers (by mass) in Size Class 4. Therefore,

$$M_1 = \frac{0.26 \cdot 0.3}{0.26 \cdot 0.3 + 0.39 \cdot 0.75 + 0.28 \cdot 1.25 + 0.07 \cdot 1.5} = 0.09 = 9\%$$

The percent of bypassed fibers by mass that are in Size Class 1 (0.1 mm to 0.5 mm in length) for 2008 Bypass Tests 1 and 2 was calculated to be 9%.

If it is assumed that fibers that have a length less than 0.5 mm (500 microns) are not collected by the fiber bypass capture screen, then the mass of bypass debris reported is potentially underestimated.

It is conservative to model all fibers less than 0.5 mm in length as bypassing the fiber bypass capture screen. Therefore, to account for the potential for increased fiber bypass of small fibers through the 0.31 mm mesh, the mass of fibers that bypass the strainer will be increased by 9%.

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2) ***The location of the screen in the test loop was not clear. Could turbulence in the flume have prevented some fiber from collecting on the screen or washed some of the fiber from the screen?***

The fiber bypass capture screen is a three sided "basket" located in the test flume with one side between the sparger and strainer, one side lining the end of the Multi-Functional Test Loop (MFTL) upstream of the sparger, and one side lining the bottom of the MFTL between the two vertical sides.

It is possible that turbulence in the test flume could cause some fiber redistribution on the fiber bypass capture screen. This is not expected to result in reduced bypass quantities due to the procedures in place to collect fiber that may have fallen off of the fiber bypass collection screen prior to determining the mass of bypass fibers (See Question 3).

3) ***Discuss the procedures for handling the collection screens. How was debris ensured not to fall off the screen when it was removed, during drain down, handling, drying, etc?***

Prior to test initiation, a clean, dry fiber bypass capture screen is weighed and installed in the clean test loop. The clean test loop is then filled and the test commences. The fiber bypass capture screen is not removed during the test, thus minimizing the chance for captured fiber to fall off the capture screen. Furthermore, the fibers are continually compressed on the fiber bypass capture screen by the flow through the flume, thus helping to keep the fibers on the capture screen.

Once the test is complete, the flow is stopped and the test loop is drained. Then the fiber bypass capture screen is carefully removed. Prior to cleaning the test loop, the walls of the MFTL upstream of the fiber bypass capture screen are carefully checked for residual fiber. Any fiber that is found is included in the total bypass quantity which ensures that fiber which may fall off the debris bed during draindown is accounted for. Collection of fibers not on the capture screen is simple since the fibers are wet following the tests and are therefore easy to handle.

Following removal of the fiber bypass capture screen and checking the walls for residual fiber, the fiber bypass capture screen is dried. The fiber bypass capture screen is placed horizontally in an oven, thus preventing fibers from falling off during the drying process. Once the fiber bypass capture screen is dry (see response to

Question 11), the screen is weighed in the horizontal position, thus preventing fibers from falling off during the weighing process. The difference between the final and initial bypass capture screen mass is the mass of bypassed fiber.

4) ***How was it ensured that the samples were representative of an average amount that would be present downstream of the strainer over the sample interval? For example, what was the timing of the samples compared to the debris additions? Sampling has been noted to miss higher concentration clouds of fiber that pass the strainer during debris introduction. This may not be important if the sample results are not used for evaluation of fiber amounts over time.***

The downstream grab samples were taken immediately following the first debris addition and every 3 minutes thereafter. However, the grab sample results were not used to determine the bypassed fiber amount as discussed below. Therefore, the timing of the grab samples compared to the debris additions is not relevant.

The bypass results (in terms of quantity of bypass per unit strainer area) are based on fiber bypass capture screen results (not sampling). Specifically, Figures 3f.4.2.2.1-1, 3f.4.2.2.1-2, 3f.4.2.2.2-1 and 3f.4.2.2.2-2 in Section 3f.4.2.2 of the 2012 Supplemental Response were generated based on the quantity of fibers collected on the fiber bypass capture screen.

Downstream grab samples were taken to document the transient downstream fiber concentration in 2006 (see Figure 3f.4.2.2.1-3 in Section 3f.4.2.2 of the 2012 Supplemental Response) and to determine the size distribution of the bypassed fibers in both 2006 and 2008 (see Tables 3f.4.2.2.1-1 and 3f.4.2.2.2-2 of the 2012 Supplemental Response).

5) ***The highest reported test velocities were about 80 times lower than the maximum expected velocity for the Salem strainer according to the vortex evaluation. How do velocity gradients of this magnitude affect bypass?***

Maximum Expected Velocity for Salem Strainer

The maximum approach velocity used in the vortex evaluation is 0.582 m/s based on two pump operation (See Section 3.f.3.1.1 of 2012 Supplemental Response). However, at Salem the approach velocity is not equivalent to the penetration velocity due to the pocket design of the CCI strainer. Approach velocity can be converted to penetration velocity by dividing the approach velocity by the ratio (12.4) of the total pocket area (0.124587 m^2) to the pocket approach area (0.010008 m^2 = 120 mm x 83.4 mm).

In addition, the approach velocity used in the vortex evaluation is based on the flow to the closest one third of the closest module to the sump. While this approach is used to ensure the absence of vortexing, it is too conservative for bypass which is an integrated phenomenon rather than a localized phenomenon such as vortexing. Therefore, using the spreadsheets developed as part of the strainer head loss calculation (see section 3f.9 of 2012 Supplemental Response), the maximum penetration velocity across the entire first module for a clean strainer head loss condition is determined to be 0.027 m/s. This is only 3.9 times higher than the maximum penetration velocity tested by CCI in 2006.

How Velocity Gradients at Salem Affect Bypass

The maximum computed penetration velocities discussed above are based on a clean strainer. As soon as some fiber reaches the strainer, the local penetration velocity immediately and significantly decreases. Therefore, only a small quantity of debris will be exposed to the maximum computed velocities. In fact, most debris will be exposed to penetration velocities both significantly less than the maximum velocity and close to the penetration velocities tested.

The 2008 CCI fiber bypass tests determine the design basis fiber bypass quantity based on a uniform penetration velocity of 0.0014 m/s over all strainer modules per CCI Report 680/41465. While these tests underestimate the penetration velocity through several of the modules closest to the sump, they overestimate the penetration velocity through most of the modules further from the sump.

To illustrate this point, a plot of the expected penetration velocities immediately after recirculation initiation and after 1/3 of a pool turnover is shown below. Note, while the strainer and sump pit fill with water before recirculation begins, approximately 2.3% of the fiber will reach the strainer (based on the volume of water in the strainer compared to the volume of water in the sump pool at recirculation initiation assuming uniform debris concentration). The Unit 1 debris load is selected since it has a less uniform penetration velocity distribution due to a lower overall debris head loss than Unit 2 (see Section 3f.10.2 of 2012 Supplemental Response); however, the debris load is conservatively applied to the Unit 2 strainer since it is smaller and therefore has higher penetration velocities. The plot of expected penetration velocity in each module was generated using the spreadsheets developed as part of the strainer head loss calculation (see Section 3f.9 of 2012 Supplemental Response). Based on a uniform debris concentration in the sump pool, two pump flow, and the strainer head loss being directly proportional to the quantity of debris on the strainer, it is expected that the penetration velocity profiles shown in the figure below would develop quickly after recirculation initiation and after 1/3 of a pool turnover.

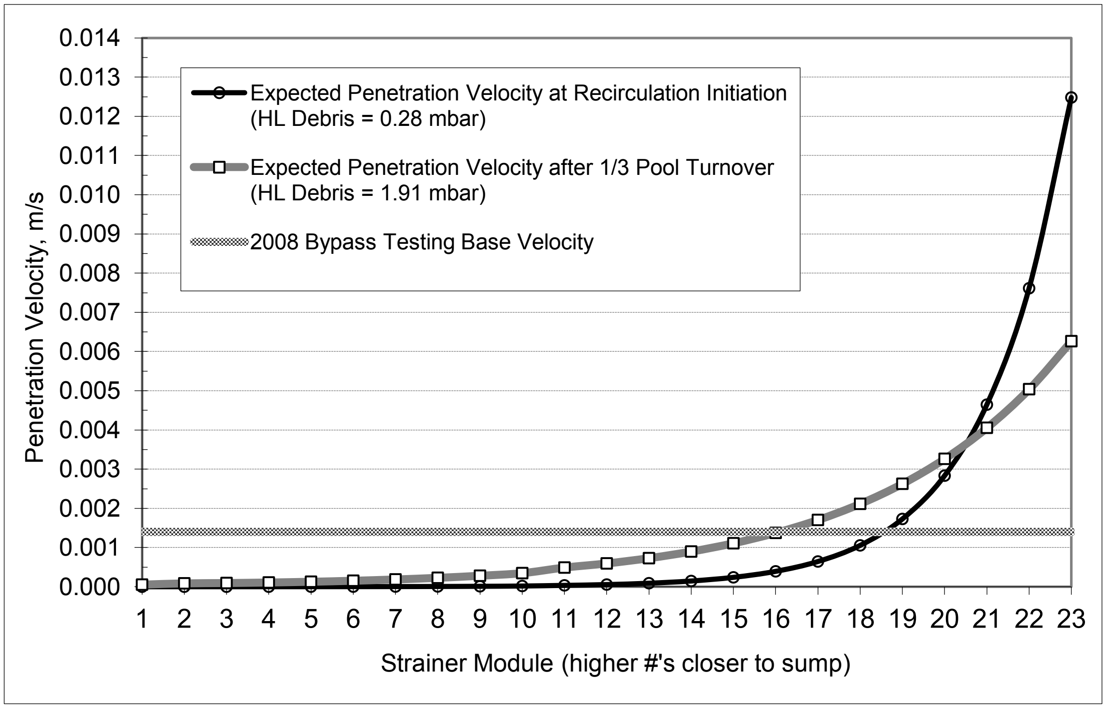

Figure 5-1: Penetration Velocity Distribution

As shown in Figure 5-1, it is expected that at recirculation initiation approximately 75% of the strainer modules will experience penetration velocities lower than those tested in the 2008 CCI Bypass Tests. Furthermore, by the time 1/3 of a pool turnover has occurred (approximately 5 minutes after recirculation begins), the penetration velocities at the modules nearest the sump are already significantly lower.

Non-uniform velocities could result in modules nearer the sump having a greater quantity of debris than modules farther from the sump due to the higher module approach velocities near the sump. The higher velocities could result in potentially more bypass in the modules near the sump. However, the results of bypass testing which give the mass of bypassed fibers per unit area based on a uniform debris bed/velocity show that additional fiber bypass does not occur beyond a saturation value which was reached during testing (See Question 6). Therefore, application of the test results (bypass/area) could result in conservative results for modules farther from the sump since those modules may not achieve a saturation fiber quantity.

For these reasons, the net effect of assuming a uniform velocity gradient when determining the fiber bypass quantity is expected to result in a best-estimate assessment of the total fiber bypass per unit area. Therefore, the velocity gradient across the strainer train will not adversely impact the design basis fiber bypass results.

6) ***Related to the velocity question above, is using bypass per strainer area valid? Does a larger plant strainer area compared to the test strainer area result in linearly greater bypass or is it some other function? Would the larger plant strainer result in a less uniform debris deposition resulting in a change in bypass? How well do the bypass tests conducted validate this relationship?***

The use of the existing strainer bypass results for larger strainers with velocity gradients within the strainer train is addressed in the response to Question 5. Therefore, this response focuses on the other portions of this question.

The Salem fiber bypass test results demonstrate that the strainers reach a fiber saturation point as tests with significantly different uniformly distributed debris loads yielded similar results. Thus, the Salem tests validate the use of bypass per area instead of other measurements (e.g. bypass equal to a fraction of the total debris). Since the Salem fiber bypass measurements are obtained in tests with uniform debris beds (due to flume agitation), the results represent a reasonable upper bound for the fiber bypass quantity per area; i.e. it is unlikely that any more fiber could bypass the strainer than was observed in the tests.

In a larger strainer with a potentially non-uniform debris bed, some modules would be exposed to more debris than in the test, while others would be exposed to less debris. Given that the maximum amount of bypass is established by the saturation fiber quantity (obtained in the tests prior to reaching the full fiber debris load), the modules exposed to more debris than in the test will bypass a similar amount of fiber as the modules in the test. However, the modules exposed to less debris (if insufficient to be saturated with fiber) will bypass less fiber than the modules in the test. Thus, extrapolating the fiber bypass results from the tests to a large strainer is conservative even if the larger strainers have a non-uniform debris bed.

Further analysis of the 2006 and 2008 fiber bypass testing data also validates both the use of bypass per strainer area as a measurement and the application of test results to a larger strainer. Although both the 2006 and 2008 tests utilized a fixed test strainer area, they also tested markedly different debris loads. Tests 1-4 in 2006 tested debris loads ranging from approximately 100 ft^3 to 2600 ft^3 of equivalent NUKON and resulted in similar bypass quantities (i.e. Test 2 did not experience 26 times the bypass of Test 4). Similarly, Tests 1-3 in 2008 tested debris loads ranging from approximately 10 ft^3 to 500 ft^3 of equivalent NUKON and resulted in similar bypass quantities (i.e. Test 1 did not experience 50 times the bypass of Test 3). The tests with smaller debris loads result in debris beds equivalent to those which would be obtained by testing a larger debris load on a much larger strainer, ceteris paribus. For instance, a test with 100 ft^3 of equivalent NUKON results in a similar debris bed to a 2600 ft^3 equivalent NUKON debris load on a strainer approximately 26 times larger than the test strainer assembly. Thus, the test results validate the application of the results to strainers larger than the test module.

See the responses to Questions 9 and 16 for a presentation of the bypass test results and debris loads, respectively.

7) ***Was sensitivity to water chemistry evaluated?***

The CCI Bypass Tests, which used tap water for all testing, did not evaluate sensitivity to water chemistry. A presentation given at the October 18-19, 2012, NEI PWR Sump Performance (GSI-191) Workshop summarizes the Texas A&M University (TAMU) experiments conducted by STP to study the sensitivity of water type on debris bypass. These tests, which represent the current industry knowledge base on this topic, indicated that there is no significant difference in bypass quantity when using tap water instead of buffered/borated DI-Water.

8) ***What were the batch sizes and what was the time interval between each batch? (Batch size may be expressed as a theoretical debris bed thickness). Large batch sizes could result in a debris bed forming more quickly than would actually occur in the plant, resulting in and less bypass.***

Table 8-1 gives the batch sizes and time intervals between debris additions for the 2008 Fiber Bypass Tests.

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Table 8-1: Bypass Testing Batch Size Summary

Bypass Test	Portion	Bucket	Elapsed Time From 1st Addition, min	Number of Turnovers After 1st Debris Addition (Note b)	NUKON, kg	Kaowool, kg	Fiberglas, kg	Theoretical Debris Bed Thickness, in	Incremental Theoretical Debris Bed Thickness Added, in
2008 Bypass Test 1	1	1	0	0	0.496	-	-	0.09	0.09
		2	4(a)	1	-	-	0.641	0.16	0.07
		3	8(a)	3	-	0.339	-	0.18	0.02
		4	12(a)	4	0.576	-	-	0.29	0.11
		5	16	6	-	0.229	0.104	0.31	0.02
	2	1	30	11	0.573	-	-	0.42	0.11
		2	38(a)	14	0.573	-	-	0.53	0.11
		3	46(a)	17	-	-	0.641	0.60	0.07
		4	54	20	-	0.509	-	0.63	0.03
	3	1	54	20	0.573	-	-	0.73	0.11
		2	86(a)	32	0.573	-	-	0.84	0.11
		3	118	44	-	0.424	-	0.86	0.02
	4	1	125	46	0.516	-	-	0.96	0.10
		2	135(a)	50	0.516	-	-	1.05	0.10
		3	145	54	-	0.424	-	1.08	0.02
	Average Incremental Theoretical Debris Bed Thickness:								*0.07*
2008 Bypass Test 2	1	1	0	0	0.440	-	-	0.08	0.08
		2	2.6(a)	1	-	-	0.552	0.14	0.06
		3	5.2(a)	2	-	-	0.552	0.21	0.06
		4	7.8(a)	3	-	0.669	-	0.24	0.04
		5	10.4(a)	4	-	0.669	-	0.28	0.04
		6	13	5	0.081	0.182	0.089	0.32	0.04
	Average Incremental Theoretical Debris Bed Thickness:								*0.05*
2008 Bypass Test 3	1	1	0	0	0.147	-	-	0.03	0.03
		2	7	3	0.048	-	-	0.04	0.01
	Average Incremental Theoretical Debris Bed Thickness:								*0.02*

(a) The bucket addition elapsed time is linearly interpolated between the portion start and end times.
(b) Test loop turnover time is approximately 2.7 minutes.

The batch sizes used for Bypass Tests 1, 2 and 3 in 2008 resulted in theoretical debris bed thickness additions less than 1/8 inch (0.01 to 0.11 inches) and therefore are not expected to result in unrealistically low fiber bypass values. Furthermore, the debris prepared in each bucket was added to the test loop with a pitcher (see photo 10-2 in response to Question 10). Thus the actual addition sizes are even smaller.

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9) What were the test results in lb of bypass? How will the results be used? Will a single maximum value be used or will a time dependent debris load be calculated?

Bypass testing results are used in the Downstream Wear Calculation and Fuel Deposition (In-Vessel Downstream Effects) Calculation.

Some of the results presented graphically in Section 3f.4.2.2 of the 2012 Supplemental Response are repeated below.

Table 9-1: 2006 Fiber Bypass Results Summary

	Measured Fiber Bypass From Testing, [lb_m / 1000 ft^2]	Fiber Bypass [ft^3/1000 ft^2]
2006 Bypass Test 1	2.03	1.05[(a)]
2006 Bypass Test 2	3.36	1.12[(b)]
2006 Bypass Test 3a	1.56	0.80[(a)]
2006 Bypass Test 4	2.11	1.09[(a)]

(a) As-measured density of NUKON (1.94 lb_m / ft^3) is used for conversion from lb_m / 1000 ft^2 to ft^3 / 1000 ft^2.

(b) The conversion from lb_m / 1000 ft^2 to ft^3 / 1000 ft^2 is performed using a density of 3 lb_m/ft^3. This density is the average of the as-measured density of NUKON (1.94 lb_m / ft^3) and the as-measured density of Kaowool (4.1 lb_m / ft^3).

The average fiber bypass from the four 2006 non-latent debris load tests (1.015 ft^3 / 1000 ft^2) presented in Table 9-1, plus margin, is used in the Downstream Wear Calculation (actual value used is 1.307 ft^3/1000 ft^2). As discussed in Section 3m.3 of the 2012 Supplemental Response, Appendix B of the Downstream Wear Calculation calculated a fiber bypass fraction of 1.4 % (using the data above), resulting in an initial fiber removal efficiency of 98%. For conservatism, a value of 97% was used in the long term wear effects evaluation. The Downstream Wear Calculation was not revised to utilize the more prototypical 2008 bypass results since the 2006 bypass results are conservative relative to the 2008 results.

Table 9-2: 2008 Fiber Bypass Results Summary

	Measured Fiber Bypass From Testing [lb_m / 1000 ft^2]
2008 Bypass Test 1	**0.85**[(a)]
2008 Bypass Test 2	0.51
2008 Bypass Test 3	0.68
2008 Bypass Test (Average)	0.68

(a) Maximum value from 2008 bypass testing is used in Fuel Deposition Calculation

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The fiber bypass quantity used for the existing Fuel Deposition Calculation is 0.85 lb_m / 1000 ft^2. This is based on CCI Bypass Test 1 in 2008 (see Figure 3f.4.2.2.2-2 in the 2012 Supplemental Response). The results of Bypass Test 1 in 2008 were used since they result in a conservatively greater bypass quantity than the results of Bypass Tests 2 and 3 in 2008.

10) Discuss the procedures for debris control during the tests. How were the fibers ensured to all make it into the test tank after weighing and preparation?

The dry fiber material was weighed in separate buckets which were labeled with tape (see Photo 10-1). The dry material was then further divided into batches which were soaked with water prior to being blasted with a water jet. The fiber batches were placed in larger bucket(s) in order to accommodate water from the jet blasting. The quantity of debris in these larger buckets was also recorded and placed on a tape label on the bucket (red circle in Photo 10-2). The large buckets were not drained during the water jet blasting to ensure that no fiber fines were lost. The prepared fiber debris bucket was then placed on a scaffold near the MFTL and the fiber slurry was added to the test loop using the dip-bucket method where a pitcher was used to slowly add the debris to the MFTL (green circle in Photo 10-2).

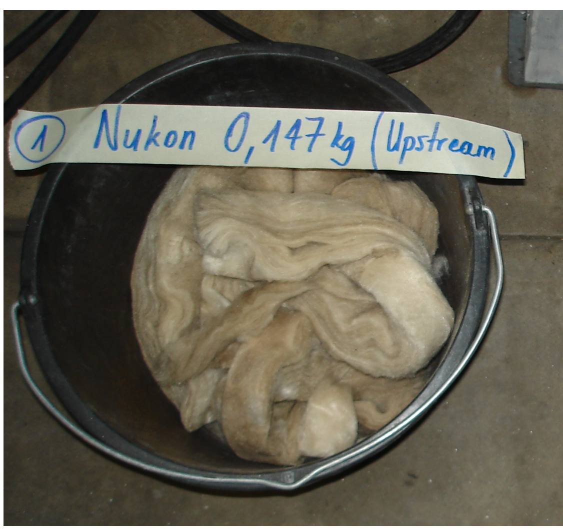

Photo 10-1

Photo 10-2

Furthermore, given that the results of the fiber bypass tests indicate that the strainer reaches a fiber saturation value beyond which additional fiber does not result in significant bypass, the loss of a few fibers during preparation and addition would be inconsequential.

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11) ***Discuss the controls in place for verifying an accurate weight of fiber in the collection screen. How was the drying process for the screen controlled before being weighed and inserted into the loop?***

Prior to each fiber bypass test, the clean fiber bypass capture screen was dried in an oven at 100°C (212°F) for 24 hours to ensure the dryness of the screen prior to measuring the initial (pre-test) weight of the screen.

Once the fiber bypass capture screen was removed from the test loop (post-test), it was dried in an oven at 100°C (212°F) for 24 hours prior to being removed and weighed. This is long enough to ensure a completely dry fiber bypass capture screen based on CCI's experience which has shown that 70°C for 12 hours is actually sufficient for complete drying. The final weight of the fiber bypass capture screen (including dried fibers) was then compared to the initial (pre-test) weight to determine the mass of bypassed fiber collected on the capture screen. In the unlikely event that the fiber bypass capture screen was not completely dry after 24 hours, it would result in conservative fiber bypass results since the residual water mass would be included in the bypass mass.

Weight measurements in the 2008 fiber bypass tests were performed using a calibrated scale accurate to the 0.0001 kg (0.1 g) place (Section 3f.4.1.6.6 of the 2012 Supplemental Response).

The above process was only performed once per test since the fiber bypass capture screen was only removed after test completion (the fiber bypass capture screen was not changed during testing).

12) ***At what fiber load does bypass stop or reach a small constant value? Is this dependent on strainer size or penetration velocity? Was it determined that bypass had stopped or reduced to some small constant value prior to the tests being secured? If not, what were the termination criteria?***

Based on the results of the 2008 Fiber Bypass Tests, the amount of fiber bypass is not proportional to the amount of fiber used in the testing beyond a "saturation" value of fiber on the strainer pockets. Therefore, the values used in the 2008 tests are sufficient to show total bypass. This is supported by Figure 3f.4.2.2.2-2 of the 2012 Supplemental Response which shows the relationship between bypass quantity per strainer area and the total mass of fiber added to the test loop.

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No specific termination criteria were used in the fiber bypass tests. However, it is very likely that fiber bypass stopped prior to the test termination for all tests based on the following:

- Each of the three fiber bypass tests performed in 2008 had a test loop turnover time of approximately 2.7 minutes. During the 2008 bypass testing, the time between the final debris addition and test termination was 20.3 hours, 19.3 hours, and 5.9 hours for Bypass Tests 1, 2, and 3, respectively. Therefore, the test loop was able to turnover approximately 451, 429, and 131 times between the final debris addition and test completion for Bypass Tests 1, 2 and 3 in 2008, respectively. At Salem, 25 (Unit 2) to 54 (Unit 1) pool turnovers would occur before hot leg switchover based on the minimum time to hot leg switchover, maximum ECCS flow, and minimum pool volume.

- The total fiber bypass quantity in Test 3 is similar to the total bypass quantity in Test 1 and Test 2, despite Test 3 being run for 131 turnovers instead of 451 (Test 1) or 429 (Test 2) turnovers (see Figure 3f.4.2.2.2-2).

- The test loop water was clear at the time of the last bypass grab sample.

Based on the number of pool turnovers that occurred between the final debris addition and test completion and clear water at test termination, the time chosen to terminate the tests was appropriate. Longer bypass testing times would not be expected to result in greater fiber bypass test results.

13) Were the filters (screen) changed more than once during the test? If so, when and how were the changes performed?

The fiber bypass capture screen was not changed during the tests. It was installed prior to test initiation and removed after test completion.

14) What are the bypass amounts in the graphs included in the Salem supplemental response in Section 3.f.4.2.2 based upon (filter results or sampling)?

The bypass amounts (in terms of quantity of bypass per unit area) are based solely on fiber bypass capture screen results. Specifically, Figures 3f.4.2.2.1-1, 3f.4.2.2.1-2, 3f.4.2.2.2-1 and 3f.4.2.2.2-2 in Section 3f.4.2.2 of the 2012 Supplemental Response were generated based on the mass of fibers collected on the fiber bypass capture screen.

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Note, Figure 3f.4.2.2.1-3 in Section 3f.4.2.2 of the 2012 Supplemental Response documents the transient downstream fiber concentration and is based on grab sampling. However, this data was not used to compute the total fiber bypass quantity.

Fiber size results presented in Tables 3f.4.2.2.1-1 and 3f.4.2.2.2-2 are based on grab sampling. However, these tables are not used to calculate the bypass amount.

15) How were the debris amounts in table 3f.4.1.3.4-1 calculated? For example, in test 1 I calculate that 7.3 kg of debris should have been added. 1212.5 ft^3/180.8x2.4lb/ft^3/2.2lb/kg = 7.3 kg, not 5.9 kg.

The debris amounts in Table 3f.4.1.3.4-1 of the 2012 Supplemental Response were calculated using the as-measured density of the NUKON (31.13 kg/m^3 or 1.94 lb_m/ft^3, per CCI Report 680/41217) supplied to CCI for testing as shown in the equations below:

As-measured: $\frac{1212.5}{180.8} ft^3 \cdot 1.94 \frac{lb}{ft^3} \cdot \frac{1.0\,kg}{2.2\,lb} = 5.9\,kg$

Nominal: $\frac{1212.5}{180.8} ft^3 \cdot 2.4 \frac{lb}{ft^3} \cdot \frac{1.0\,kg}{2.2\,lb} = 7.3\,kg$

The as-measured density is the measured as-fabricated density of the fiber supplied to CCI for the 2006 bypass testing. The nominal density is the expected (data sheet) as-fabricated fiber density.

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16) Did two sided strainer tests result in a different amount of bypass when other conditions were similar to the single sided test?

The single-sided (2006) and two-sided (2008) strainer module tests are described in Sections 3f.4.1.3, 3f.4.1.6, and 3f.4.2.2 of the 2012 Supplemental Response. Parameters which differed for the tests are provided in Table 16-1.

Table 16-1: Comparison of 2006 & 2008 Fiber Bypass Test Parameters

Parameter	2006 Bypass Tests	2008 Bypass Tests
Test Module	Single sided module with top pockets blocked off	Two sided prototypical module
Baked Fiber Debris?	No	Yes (NUKON & Kaowool) No (Fiberglas)
Tested Fiber Types	NUKON, 1 test with Kaowool	NUKON, Kaowool, Fiberglas
Plant Fiber Debris Load (summation, Σ, is equivalent NUKON load where applicable based on Section 3f.4.1.5.8 of 2012 Supplemental Response)	Test 1: 1212.5 ft^3 NUKON Test 2: 606.25 ft^3 NUKON 606.25 ft^3 Kaowool $\Sigma_{equivNUKON} = 2614\ ft^3$ Test 3a: 212.5 ft^3 NUKON Test 4: 112.5 ft^3 NUKON Test 9b: 12.5 ft^3 NUKON	Test 1: 268.8 ft^3 NUKON 37.0 ft^3 Kaowool 54.6 ft^3 Fiberglas 12.5 ft^3 Latent $\Sigma_{equivNUKON} = 495\ ft^3$ Test 2: 20.9 ft^3 NUKON 29.2 ft^3 Kaowool 47.0 ft^3 Fiberglas 12.5 ft^3 Latent $\Sigma_{equivNUKON} = 208\ ft^3$ Test 3: 12.5 ft^3 NUKON
Batch Sizing	100% debris added within a short interval	Debris added in small portions
Plant Flow Rate	9000 gpm	8850 gpm
Scale Factor	180.8	69.7
Loop Turnover Time	~6 minutes	~2.7 minutes

Thus, there were no tests performed where the only difference between the tests was the strainer module in the test loop. Therefore, the impact of the strainer module by itself cannot be ascertained with certainty.

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17) ***It is difficult to evaluate the results as presented for the 2008 tests because they are given in units of volume. There were 3 different types of fiber used, all with different densities. How does each of these contribute to bypass? How were the volumetric values determined? Was some sort of average or composite density used that assumed an equal bypass of each type of fiber?***

The 2008 Bypass Testing results are presented in Figures 3f.4.2.2.2-1 and 3f.4.2.2.2-2 of the 2012 Supplemental Response. Figure 3f.4.2.2.2-1 presents the bypassed as-fabricated fiber volume per 1000 ft^2 strainer area while Figure 3f.4.2.2.2-2 presents the mass of bypassed fiber per 1000 ft^2 of strainer. The mass based results are obtained directly from the bypass tests since the tests measure the mass of bypassed fibers. The volume based results are obtained by converting the mass based results to as-fabricated volume using the as-fabricated density of NUKON (2.4 lb/ft^3). This conversion method is conservative since NUKON has the lowest density of the tested fiber debris (density of Kaowool = 8.0 lb/ft^3, density of Fiberglas = 3.9 lb/ft^3) and therefore results in the greatest bypassed fiber volume associated with the bypass mass measured in the test.

The mass based results (in lb/1000 ft^2 of strainer area) are directly used in the Fuel Deposition Calculation. Therefore, the method for converting to volume of bypassed fibers per square foot is not germane.

18) ***Discuss why a test with a larger fiber load (test 2) resulted in a lower bypass value than a test with a lower fiber load (test 3). Did 2008 test 3 form a filtering bed over the entire strainer? Could this be related to artificially fast arrival time for the fiber as discussed above with regards to fiber batch size?***

Although the fiber arrival time for Bypass Test 2 is faster than Bypass Test 3 (See Question 8), the most likely reason for Test 3 having more bypass than Test 2 is that Test 2 included other debris types (e.g. Kaowool and Fiberglas). The inclusion of Kaowool is notable in that its presence likely inhibits bypass due to the nature of the insulation. Kaowool is a needled insulation in which the individual fibers are not chemically bound, but are physically interlocked. The physical interlock results in fibers with “hooked” ends. The hooked ends could attach to any other fibers during debris preparation, effectively resulting in longer fibers which would be less likely to bypass.

Bypass Test 3 in 2008 investigated bypass with only latent fiber (tested as NUKON) and resulted in a theoretical homogenous debris bed thickness of approximately 0.036

inches or 1/28 inch. Although this is much less than the theoretical debris bed thickness of 0.32 inches obtained in Test 2, it is sufficient to form a filtering fiber bed over the entire strainer. A filtering fiber bed is one which blocks fiber bypass, but does not necessarily result in significant head loss. It should be noted that some "fast" (i.e. low head loss) laboratory grade filters effective at blocking particles 15 μm and larger have thicknesses on the order of 300-500 μm or 0.01 to 0.02 inches.