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W3F1-2010-0032

November 23, 2010

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Subject: Response to Request for Additional Information Regarding Final Supplemental Response to Generic Letter 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (TAC No. MC4729)
Waterford Steam Electric Station, Unit 3
Docket No. 50-382
License No. NPF-38

REFERENCES:

1. W3F1-2008-0069, Entergy Letter to NRC dated October 23, 2008, "Final Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized Water Reactors"
2. NRC Letter dated September 22, 2009, "Waterford Steam Electric Station, Unit 3 – Request for Additional Information Regarding Supplemental Response to Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized Water Reactors" (TAC No. MC4729)(ILN09-0095)

Dear Sir or Madam:

By letter dated October 23, 2008, Entergy Operations, Inc. (Entergy) submitted the final supplemental response to Generic Letter 2004-02 "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," (Reference 1). During the submittal review process, the Nuclear Regulatory Commission (NRC) determined that additional information was required to complete the review of the Entergy response. The Request for Additional Information (RAI) was sent to Entergy on September 22, 2009 (Reference 2). Subsequent to receipt of the RAI, there have been several teleconferences with the

A116
NRR

NRC (held on: September 15, 2009, January 11, 2010, March 8, 2010, April 5, 2010, April 7, 2010, April 16, 2010, and June 1, 2010).

The response to the RAI is included in Attachment 1 to this letter.

This letter contains 3 new commitments.

If you have any questions or require additional information, please contact William Steelman at 504-739-6685.

I declare under penalty of perjury that the foregoing is true and correct. Executed on November 23, 2010.

Sincerely,

JAK/MEM/ssf

Attachments:	1.	Response to Request for Additional Information
	2.	List of Regulatory Commitments

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U. S. Nuclear Regulatory Commission
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Attachment 1

W3F1-2010-0032

Response to Request for Additional Information

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Generic Letter 2004-02 Conservatisms

The following summarizes the more significant conservatisms in the overall Waterford 3 Generic Letter 2004-02 response:

Debris Generation and Transport Analysis

- Break analysis ignores potential for leak-before-break for Reactor Coolant System (RCS) lines and assumes an instantaneous break opening.

- In the debris transport analysis the lift-over-curb velocity used was for a 6" high curb. However, the plenum on which the Safety Injection Sump strainers sit is 8" high. In addition, the bottom disk for the strainers is approximately 3" above the plenum.

- Debris transport analysis does not credit the holdup of debris by systems, structures, or components. All debris is assumed to fall directly to the containment floor and be exposed to the recirculation flow stream.

- Waterford 3 assumed 10% of qualified coatings on the containment liner dome and the liner between elevations 112' and 138' would fail. This value far exceeds the total amount of degraded qualified coatings throughout containment recorded at Waterford 3 in Refueling Outage 16.

- All unqualified coatings are assumed to fail as particulate and transport to the strainers. In reality, some of the unqualified coatings would fail as chips and would not transport.

- All Nukon fiber debris generation is based on a 17D Zone of Influence (ZOI). Instead of using the size distribution applicable to 17D which would result in a 13.7% transport fraction, Waterford 3 used a conservative 20% fines / 80% smalls ratio which results in a 28% transport fraction.

- Debris transport analysis uses conservative 30 day fiber erosion rates to determine fiber loading at time zero.

- Debris generation analysis assumes that all coatings exist at their maximum allowed thickness.

- Debris transport analysis uses a conservatively low containment flood water level to maximize transport velocities.

- Metal Encapsulated Insulation manufactured by Transco is assumed to have a ZOI larger than the value of similarly constructed Transco Reflective Metal Insulation.

- Latent debris loads are assumed to total 250 lbm. The latent debris survey conducted in 2009 concluded only about 81 lbm exists in containment.

Head Loss Testing

- Testing does not credit the settling of debris, though during post accident recirculation the strainers exist in a low velocity region of the pool which would allow near field settling to occur.
- During testing, a full 30 day chemical precipitate load is assumed to arrive at the strainer at the earliest possible time with no credit for settling or nucleation on containment surfaces.
- During testing, metallic insulation debris is excluded from the tested debris bed in order to conservatively bound head loss.
- Testing flow rates are scaled based on plant pump run-out flows which are higher than expected plant flow rates.
- Scaling calculations conservatively ignore the bottom perforated surface of the strainers. This area in reality is still available for flow and debris adherence.
- In addition to the design basis loading and thin bed cases, an additional margin test was conducted using a 10% above design fiber debris load (chemical loads were increased accordingly).
- Mission time extrapolation curves are conservatively increased to bound all test data used to develop the logarithmic decay curve fit function.

Chemical Effects

- Strainer head loss testing uses gelatinous, amorphous forms of chemical precipitates formed with high-concentration chemical reactants, even though lower head loss crystalline forms of precipitation are expected to form in the low-species-concentration environment of the containment sump.
- 100% of dissolved aluminum and calcium is assumed to precipitate at the strainer and cause head loss. No credit for long-term solubility limits is taken, even though some aluminum and calcium can remain in solution long-term and not form precipitates.
- No credit is taken for silicon or phosphate inhibition of aluminum corrosion, even though Waterford 3 is a high-fiber, Tri-Sodium Phosphate buffered plant and inhibition of aluminum corrosion in that environment is a known phenomenon.
- The maximum sump pH profile is used for aluminum corrosion prediction to maximize the aluminum dissolution rate and cumulative amount. The minimum sump pH profile is used to determine the aluminum precipitation temperature, which results in a conservatively maximized precipitation temperature.

Ex-Vessel Downstream Effects Analysis

- 0% of the fibers that are able to pass through the screen are removed by the initial pass through the sump strainer.
- 0% of the fibers that are able to pass through the screen are removed during continuous operation of the sump strainer.
- No credit is taken for securing ECCS\CS pumps during the course of a postulated accident.
- Pump shut-off head is used where maximum dP would result in conservative wear calculations.
- Run-out flow is used when minimal head or maximum flow would result in conservative calculation results.

Water Level and Net Positive Suction Head (NPSH) Analysis

- For the NPSH calculation, flow rates are based on both trains of Emergency Core Cooling System (ECCS) and Containment Spray (CS) operating at pump run-out values. However, the temperature assumptions in containment are based on only one train of CS in operation at design flow, and ECCS at minimum flow.
- NPSH analysis uses a Loss of Coolant Accident (LOCA) water level with a break at the top of the Pressurizer. Debris limiting breaks for GSI-191 are large breaks of the primary piping and would result in a higher water level at the time of recirculation. The water level also neglects some safety related sources of water.
- NPSH analysis uses a strainer head loss that assumes all debris is present on the strainer at the time of recirculation. This is non-prototypical as the debris bed will take time to build, during which NPSH margins will increase as the plant cools.

While not all of the above conservatisms have readily quantifiable impacts to the head loss test results, the aggregate effect provides a very high degree of confidence that test results will be well bounding for any credible or design bases accident that requires sump recirculation. These multiple stacked conservatisms provide defense-in-depth to ensure that the systems and components needed to respond to a loss-of-coolant accident (LOCA) requiring sump recirculation would be able to perform their design function. Since the analysis has not relied upon credible operator actions such as securing one of the two operating trains, or securing Containment Spray pumps at the earliest allowed opportunity, an additional potential course of corrective measures has also been preserved.

Table A below provides the Net Positive Suction Head (NPSH) analysis results for Waterford 3 utilizing the most recent strainer head loss test data. Strainer head loss values are based on the Additional Margin test. The values presented are for the limiting case which is based on a bounding sump temperature of 210 °F. High Pressure Safety Injection (HPSI) pump B has the lowest margin due to a higher required NPSH though it is the same make and model as the HPSI A and A/B pumps.

Pump	Flow (GPM)	Elevation Head (ft)	Vapor Head (ft)	Suction Losses (ft)	Sump Strainer Losses (ft)	NPSHa (ft)	NPSHr (ft)	Margin (ft)
HPSI A	985	26.91	0	2.447	2.155	22.308	19.253	3.055
HPSI A/B (A Train)	985	26.91	0	3.303	2.155	21.452	18.894	2.558
HPSI B	985	26.91	0	2.395	2.155	22.360	21.765	0.595
HPSI A/B (B Train)	985	26.91	0	3.272	2.155	21.483	18.894	2.589
CS A	2250	27.24	0	2.04	2.155	23.045	18.453	4.592
CS B	2250	27.24	0	2.009	2.155	23.076	18.629	4.447

Table A: Net Positive Suction Head Requirements (Limiting case)

Following are the specific responses to the RAIs:

A. *Debris Generation/Zone-of-Influence (ZOI)*

Please respond to the following questions on debris generation testing. Note that the Pressurized-Water Reactor Owners Group (PWROG) is planning to respond to some of these issues generically. The licensee will be expected to respond to all of them. To the extent the NRC staff accepts the PWROG's generic resolution, the licensee's RAI responses may refer to the resolution document as appropriate, while adding site-specific information as needed.

<u>NRC RAI 1:</u>
Although American National Standards Institute (ANSI)/American Nuclear Society (ANS) Standard 58-2-1988, "Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Rupture," predicts higher jet centerline stagnation pressures associated with higher levels of subcooling, it is not intuitive that this would correspond to a generally conservative debris generation result. Please justify the initial debris generation test temperature and pressure with respect to the plant-specific reactor coolant system (RCS) conditions, with particular emphasis on the plant hot and cold-leg operating conditions. If ZOI reductions are also being applied to lines connecting to the pressurizer, then please also discuss the temperature and pressure conditions in these lines. Please describe results of any tests conducted at alternate temperatures and pressures to assess the variance in the destructiveness of the test jet to the initial test condition specifications.

<u>NRC RAI 2:</u>
Please describe the jacketing/insulation systems used at Waterford 3 for which the ZOI reduction is sought and compare those systems to the jacketing/insulation systems tested, demonstrating that the tested jacketing/insulation systems adequately represent the Waterford 3 jacketing/insulation system. The description should include differences in the jacketing and banding systems used for piping and other components for which the test results are applied. At a minimum, the following areas should be addressed:

a. *Please describe how the characteristic failure dimensions of the tested jacketing/insulation compared with the effective diameter of the jet at the axial placement of the target. The characteristic failure dimensions are based on the primary failure mechanisms of the jacketing system (e.g., for a stainless steel jacket held in place by three latches where all three latches must fail for the jacket to fail, then all three latches must be effectively impacted by the pressure for which the ZOI is calculated). Applying the test results to a ZOI based on a centerline pressure for relatively low L/D nozzle to target spacing would be non-conservative with respect to impacting the entire target with the calculated pressure.*
b. *Please explain whether the insulation and jacketing system used in the testing was of the same general manufacture and manufacturing process as the insulation used at Waterford 3. If not, please explain what steps were taken to ensure that the general strength of the insulation system tested was conservative with respect to the insulation*

installed at Waterford 3. For example, it is known that there were generally two very different processes used to manufacture calcium silicate insulation, whereby one type readily dissolved in water but the other type dissolved much more slowly. Such manufacturing differences could also become apparent in debris generation testing as well.

c. *Please provide the results of an evaluation of scaling the strength of the jacketing or encapsulation systems compare to the tests. For example, a latching system on a 30-inch diameter pipe within a ZOI could be stressed much more than a latching system on a 10-inch pipe in a scaled ZOI test. If the latches used in the testing and the plants are the same, the latches in the testing could be significantly under-stressed. If a prototypically sized target were impacted by an undersized jet, it would similarly be under-stressed. Evaluations of banding, jacketing, rivets, screws, etc., should be made. For example, scaling the strength of the jacketing was discussed in the Ontario Power Generation report, "Jet Impact Tests -Preliminary Results and Their Application, N-REP-3432010000," dated April 18, 2001 (ADAMS Accession No. ML020290085), on calcium silicate debris generation testing.*

NRC RAI 3:

There are relatively large uncertainties associated with calculating of jet stagnation pressures and ZOIs for both the test and the plant conditions based on the models used in the WCAP reports. Please describe steps were taken to ensure that the calculations resulted in conservative estimates of these values. Please provide the inputs for these calculations and describe the sources of the inputs.

NRC RAI 4:

Please describe the procedure and assumptions for using the ANSI/ANS-58-21988 standard to calculate the test jet stagnation pressures at specific locations downrange from the test nozzle. As part of this description, please address the following points.

a *In Westinghouse Topical Report (TR) WCAP 16710-P, "Jet Impingement Testing to Determine the zone of Influence (ZOI) of Min K and NUKON Insulation, for Wolf Creek and Callaway Nuclear Operating Plants," please explain why the analysis was based on the initial condition of 530 degrees Fahrenheit (°F) whereas the initial test temperature was specified as 550 °F.*

b. *Please explain whether the water subcooling used in the analysis was that of the initial tank temperature or the temperature of the water in the pipe next to the rupture disk. Test data indicated that the water in the piping had cooled below that of the test tank.*

c. *The break mass flow rate is a key input to the ANSI/ANS-58-2-1988 standard. Please explain how the associated debris generation test mass flow rate was determined. If the experimental volumetric flow was used, then explain how the mass flow was calculated from the volumetric flow given the considerations of potential two-phase flow and temperature-dependent water and vapor densities. If the mass flow was analytically determined, then describe the analytical method used to calculate the mass flow rate.*

d. *Noting the extremely rapid decrease in nozzle pressure and flow rate illustrated in the test plots in the first tenths of a second, please explain how the transient behavior was considered in the application of the ANSI/ANS-58-2-1988 standard. Specifically, please* *explain whether the inputs to the standard represented the initial conditions or the conditions after the first extremely rapid transient (e.g., at one tenth of a second).*

e. *Given the extreme initial transient behavior of the jet, please justify the use of the steady-state ANSI/ANS-58-2-1988 standard jet expansion model to determine the jet centerline stagnation pressures rather than experimentally measuring the pressures.*

NRC RAI 5:

Please describe the procedure used to calculate the isobar volumes used in determining the equivalent spherical ZOI radii using the ANSI/ANS-58-2-1988 standard. Please include discussions of the following points.

a. *Please provide the assumed plant-specific RCS temperatures and pressures and break sizes used in the calculation. Note that the isobar volumes would be different for a hot-leg break than for a cold-leg break since the degree of subcooling is a direct input to the ANSI/ANS-58-2-1988 standard and which affects the diameter of the jet. Note than an under-calculated isobar volume would result in an under-calculated ZOI radius.*
b. *Please describe the calculational method used to estimate the plant-specific and break-specific mass flow rate for the postulated plant loss-of-coolant accident (LOCA), which was used as input to the standard for calculating isobar volumes.*
c. *Given that the degree of subcooling is an input parameter to the ANSI/ANS-58-2-1988 standard and that this parameter affects the pressure isobar volumes, please describe the steps taken to ensure that the isobar volumes conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections. Please explain whether multiple break conditions were calculated to ensure a conservative specification of the ZOI radii.*

NRC RAI 6:

Please provide a detailed description of the test apparatus, specifically including the piping from the pressurized test tank to the exit nozzle including the rupture disk system. Please also address the following related points.

a. *Please explain how the hydraulic resistance of the test piping which affected the test flow characteristics was evaluated with respect to a postulated plant-specific LOCA break flow, where such resistance would not be present.*
b. *Please provide the specified rupture differential pressure of the rupture disks.*

NRC RAI 7:

WCAP 16710-P discusses the shock wave resulting from the instantaneous rupture of piping. Please address the following points regarding the shock wave:

a. *Please describe whether results of analysis or parametric testing conducted to get an idea of the sensitivity of the potential to form a shock wave at different thermal-hydraulic conditions. Please state and justify whether temperatures and pressures prototypical of pressurized-water reactor (PWR) hot legs (or pressurizer lines) were considered.*
b. *Please explain whether the initial lower temperature of the fluid near the test nozzle was taken into consideration in the evaluation, and if not, why not. Specifically, please explain*

and justify whether the damage potential was assessed as a function of the degree of subcooling in the test initial conditions.

c. *Please provide the basis for scaling a shock wave from the reduced-scale nozzle opening area tested to the break opening area for a limiting rupture in the actual plant piping system.*
d. *Please compare how the effect of a shock wave was scaled with distance for both the test nozzle, and compare that with the expected plant condition.*

NRC RAI 8:

Please provide the basis for concluding that a jet impact on piping insulation with a 45 degree seam orientation is a limiting condition for the destruction of insulation installed on steam generators, pressurizers, reactor coolant pumps, and other non-piping components in the containment. For instance, considering a break near the steam generator nozzle, once insulation panels on the steam generator directly adjacent to the break are destroyed, the LOCA jet could impact additional insulation panels on the generator from an exposed end, potentially causing damage at significantly larger distances than for the insulation configuration on piping that was tested. Furthermore, it is not clear that the banding and latching mechanisms of the insulation panels on a steam generator or other RCS components provide the same measure of protection against a LOCA jet as those of the piping insulation that was tested. Although WCAP-16710-P asserts that a jet at Wolf Creek or Callaway nuclear plants cannot directly impact the steam generator, but will flow parallel to it, it seems that some damage to the steam generator insulation could occur near the break, with the parallel flow then jetting under the surviving insulation, perhaps to a much greater extent than predicted by the testing. Similar damage could occur to other component insulation. Please provide a technical basis to demonstrate that the test results for piping insulation are prototypical or conservative of the degree of damage that would occur to insulation on steam generators and other non-piping components in the containment.

NRC RAI 9:

Some piping oriented axially with respect to the break location (including the ruptured pipe itself) could have insulation stripped off near the break. Once this insulation is stripped away, succeeding segments of insulation will have one open end exposed directly to the LOCA jet, which appears to be a more vulnerable configuration than the configuration tested by Westinghouse. As a result, damage would seemingly be capable of propagating along an axially oriented pipe significantly beyond the distances calculated by Westinghouse. Please provide a technical basis to demonstrate that the reduced ZOIs calculated for the piping configuration tested are prototypical or conservative with respect to the degree of damage that would occur to insulation on piping lines oriented axially with respect to the break location.

NRC RAI 10:

WCAP-16710-P noted damage to the cloth blankets that cover the fiberglass insulation, in some cases resulting in the release of fiberglass. The tears in the cloth covering were attributed to the steel jacket or the test fixture and not the steam jet. Please justify the assumption that damage that occurs to the target during the test would not be likely to occur in the plant. Please explain whether the potential for damage to plant insulation from similar *conditions was considered. For example, the test fixture could represent a piping component or support, or other nearby structural member. Please provide the basis for the statement in the WCAP that damage similar to that which occurred to the end pieces would not be expected to occur in the plant. It is likely that a break in the plant will result in a much more chaotic condition than that which occurred in testing. Therefore, it would be more likely for the insulation to be damaged by either the jacketing or other objects nearby.*

WF3 Response 1-10:
The WCAP-16710-P report was originally utilized by Waterford 3 to credit a reduced ZOI of 7D for Jacketed Nukon. Waterford 3 will be replacing its Steam Generators during Refueling Outage 17 (RF-17) in the spring of 2011. The replacement generators are being procured with 100% Transco Reflective Metal Insulation. This will significantly reduce the amount of fibrous insulation in each of the two D-rings. After replacement, a ZOI reduction for Jacketed Nukon will not provide significant fiber reduction. Therefore, after Steam Generator replacement, Waterford 3 will no longer credit a reduced ZOI for Jacketed Nukon and the NEI 04-07 value of 17D will be utilized for all Nukon insulation. The fibrous debris generated with the replacement Steam Generators totals approximately 770 ft^3 (approximately 216 ft^3 transports). This compares to the previous generated quantity of 1085.6 ft^3 (590.74 ft^3 transports) based on the reduced 7D ZOI.

Commitment 1: Waterford 3 will replace the fibrous insulation on the steam generators with Reflective Metal Insulation during RF-17.

B. Debris Characteristics

NRC RAI 11:
The NRC staff review noted one critical change in the October 23, 2008, supplement versus the February 29, 2008, supplement and the NRC staff's report of its audit of Waterford 3 corrective actions for GL 2004-02, dated January 28, 2008 (ADAMS Accession No. ML080140315). The earlier two documents refer to the metal encapsulated insulation (MEI) debris being 100 percent fines. However, the October supplement refers to this MEI debris being 20 percent fines and 80 percent small pieces. Although the distinction was not used to change the analytical transport results, presumably this information was used to determine debris for head loss testing, and as such is significant. It is not clear that a debris mix of 20 percent fines / 80 percent small pieces is conservative when a 4 diameter (D) ZOI is assumed. The categorization of the debris as 20 percent fines is based on NUREG/CR-6369, "Drywell Debris Transport Study: Experimental Work," dated September 1999 (ADAMS Accession No. ML00376871), results from tests with 7-10D ZOIs, and it is an average value, not a maximum value, from these tests. Please substantiate the adequacy of the assumption that no more than 20 percent of the MEI debris within a 4D ZOI will be destroyed into fines.

WF3 Response 11:
Based on planned changes to the guidance on ZOI sizes for certain materials in the NEI 04-07 SER, Waterford 3 has adjusted the ZOI size for the Metal Encapsulated Insulation.

The revised guidance is expected to require licensees to adjust the ZOI size for certain insulation materials based on the diameter of the insulation target. This guidance comes from Table 2 of the BWR utility resolution guide (URG) [NEDO-32686, "Utility Resolution

Guidance for ECCS Suction Strainer Blockage", Revision 0, November 1996]. Footnote 3 on this table specifies that the destruction pressure for insulation such as Transco RMI, Jacketed Nukon with Sure-Hold bands, Mirror RMI, and Cal-Sil with aluminum jacketing must be adjusted using the following equation:

$$P_{dest}(i) = P_{dest\ 12"\ pipe}\ [r_{i\ 12"\ pipe} / r_i]$$

Since MEI is fiberglass insulation that is encapsulated in a manner that is identical to Transco RMI, the destruction pressure for MEI and Transco RMI would be essentially the same. Table 3-2 in the SER specifies a destruction pressure of 114 psig for Transco RMI on 12" piping [NEI 04-07 Volume 2, "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Nuclear Energy Institute Guidance Report 'Pressurized Water Reactor Sump Performance Methodology'", December 2004].

At Waterford 3, the majority of the MEI is located on the 42" hot leg and 30" cold leg piping. MEI is also installed on some smaller (≤14") piping. Therefore, the adjusted bounding destruction pressure for the MEI on the hot leg would be:

$$P_{dest}(42"\ \text{pipe}) = 114\ \text{psig}\ [6" / 21"] = 33\ \text{psig}$$

Using Figure 3.1 in the Alion debris size distribution report, a destruction pressure of 33 psig is equivalent to a 4.6D ZOI [ALION-REP-ALION-2806-01, "Insulation Debris Size Distribution for use in GSI-191 Resolution", Revision 3, April 13, 2006]. To account for any potential differences between encapsulated fiberglass and encapsulated metal foils the MEI ZOI size will be conservatively increased to 7D. Note that the 7D ZOI size will be used for the insulation on all MEI insulated lines regardless of size. This is conservative since the smaller piping has a significantly smaller diameter, and therefore would have a higher adjusted destruction pressure and a smaller ZOI.

Based on the proprietary Alion debris size distribution report, low density fiberglass debris generated within a 7D sub-zone around the break would have a distribution of 20% fines and 80% small pieces [ALION-REP-ALION-2806-01, "Insulation Debris Size Distribution for use in GSI-191 Resolution," Revision 3, April 13, 2006]. Since a 7D ZOI will be used for the Waterford 3 MEI, it is reasonable to use the 20% fines and 80% small pieces size distribution.

C. Debris Transport

<u>NRC RAI 12:</u>
Please provide a description of the testing performed to support the assumption of 10 percent erosion of fibrous debris pieces in the containment pool. As part of this description, please address the following points.

a. Please describe the test facility used and demonstrate the similarity of the flow conditions (velocity and turbulence), chemical conditions, and fibrous material present in the erosion tests to the analogous conditions applicable to the plant condition.
b. Please estimate the quantity of fibrous debris that settled in the test flume and discuss how erosion of this debris was accounted for in the strainer performance analysis. In

addition, please provide specific justification for any erosion tests conducted at a minimum tumbling velocity if debris settling was credited in the test flume for velocities in excess of this value.

c. *Please discuss how the erosion testing conducted for Waterford 3 accounts for the erosion of debris that settles in front of the strainer plenum, which may be exposed to a higher velocity than the initial tumbling velocity.*

WF3 Response 12:

Waterford 3 participated in the Alion erosion testing program. The latest round of confirmatory testing was performed in accordance with ALION-PLN-ALION-I006-02 which has been reviewed by the NRC staff. The results of the confirmatory testing, documented in ALION-REP-ALION-I006-04, conclude that the 10% erosion factor for Nukon is conservative.

The confirmatory fiber erosion testing was performed at the Alion hydraulics test laboratory in Warrenville, IL. The fiber samples were placed on racks in a test flume. A 5 micron filter was installed on the suction end of the flume to capture any fiber fines released from the samples. To minimize the introduction of latent debris, a 25 micron pre-filter was also installed on the flow straightener at the upstream end of the flume, and a solid cover was placed on top of the flume.

Further details of test facilities and set up can be found in ALION-REP-ALION-I006-04, "Erosion Testing of Small Pieces of Low Density Fiberglass Debris – Test Report," Revision 0, which has been submitted to the NRC Staff by Alion [ADAMS Document Number ML101090490].

With respect to flow conditions (velocity and turbulence), the test conditions bound the plant conditions at Waterford 3 as documented in ALION-REP-ENT-4536-02, "Waterford Unit 3 Low Density Fiberglass Debris Erosion Testing Report," Revision 1. Waterford 3 average velocity, weighted by quantity of settled fiber experiencing the flow in each location, is 0.10 ft/s, with an average turbulent kinetic energy (TKE), weighted similarly, of 0.0005 (ft^2/s^2). The confirmatory fiber erosion tests were conducted utilizing a target flow velocity and target average TKE which bounded the Waterford 3 values.

With respect to chemical conditions, to prevent potential contamination of the samples from the minerals in the tap water, de-ionized water was selected for the confirmatory fiber erosion testing. In prototypical Waterford 3 plant conditions, the containment pool water is borated and buffered. Based on observations during chemical effects testing, chemical precipitates may accumulate on exposed fiberglass. This can significantly reduce the potential for erosion to occur. The use of DI water conservatively eliminated this phenomenon during erosion testing.

The fibrous material tested was Nukon low density fiberglass. Waterford 3 applied the fiber erosion fraction to Nukon and Metal Encapsulated Insulation (MEI). The fiberglass used in MEI is composed of Owens Corning FIBERGLAS™ TIW Type II which is equivalent to Nukon. Therefore, the tested material compares well to Waterford 3 insulation materials.

Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance and did not credit near field settling. Therefore, the erosion of settled debris in the test flume is no longer a concern.

NRC RAI 13:

Please identify the size distribution of the MEI calculated as reaching the strainers in Tables 3.e.6.1 through 3.e.6.5 in the supplemental letters dated February 29 and October 23, 2008. Specifically, identify what fraction of this debris is fines, and what fraction is small pieces. Please also identify the size distribution of MEI added to the head loss tests used for strainer qualification.

WF3 Response 13:

As previously stated in RAI 11, MEI transport is based on a generation of 20% fines and 80% small pieces with an erosion factor of 10%. The table below shows the MEI transport fraction for all breaks. For the S7 break, closest break to strainer, 100% of the generated debris is assumed to transport.

Fraction of Debris at Sump				
	S6	S5	S1, S3, S4	S7
Fines	0.20	0.20	0.20	1.00
Small	0.08	0.08	0.08	0.00
Large	0.00	0.00	0.00	0.00
Intact	0.00	0.00	0.00	0.00
Sum	0.28	0.28	0.28	1.00

Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance. The fiber debris size for all tests was "fines" as per NUREG/CR-6224 Classes 1-3.

NRC RAI 14:

The supplemental response stated that module testing credited near-field settlement. However, insufficient information was provided in the supplemental response dated October 23, 2008, to provide assurance that the flow conditions simulated in the strainer head loss test flume are prototypical or conservative with respect to the plant conditions. Therefore, please provide the following information regarding the modeling of flow and turbulence in the test and how test flow conditions compared with flow conditions in the plant.

a. Please provide contour plots of the velocity and turbulence in the containment pool for Break S7 (supplements dated February 29 and October 23, 2008) and the limiting (with respect to strainer head loss) large-break case.
b. Please provide close-up plots of the velocity and turbulence contours in the vicinity of the strainer for these cases.
c. Please identify the head loss test flume (average) velocity used for the strainer module testing for these cases and the basis for the velocity chosen.
d. Please identify the turbulence levels simulated in the test flume for these test cases and provide the basis for considering them representative of the plant condition.

WF3 Response 14:
Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance. The general Alion test protocols have been observed by the NRC Staff as documented in Trip Report ML090500230. The testing did not credit near field settling, therefore; this RAI is no longer applicable.

NRC RAI 15:
The supplemental response dated October 23, 2008, stated that the test strainer had 10 disks rather than the 17 disks present on the actual plant strainers. Please describe how this difference in strainer size (and total module flow rate) was accounted for in scaling the velocity and turbulence in the head loss test flume based on geometric similarity.

WF3 Response 15:
Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance and did not credit near field settling. The general Alion test protocols have been observed by the NRC Staff as documented in Trip Report ML090500230.

The Waterford 3 test strainer module replicates all hydraulic dimensions of the Waterford 3 plant strainer except for number of strainer gaps. Therefore, debris and flow rate scaling can be performed without adjustments due to net flow area or strainer geometry since these are accounted for in the test article; scaling can be performed based only on the numbers of strainer gaps and accounting for the sacrificial strainer area due to labels and tags. The Waterford 3 plant strainer consists of 11 stacks of 17 disks (or 16 gaps each), which yields a total of 176 strainer gaps. The test strainer used 7 disks in a single module for a total of 6 gaps.

$$ScalingRatio = \frac{Gaps_{Test}}{Gaps_{Plant}} = \frac{6}{176} = 0.03409$$

The scaling ratio must be adjusted to account for sacrificial (blocked) plant strainer area including a 0.75 overlap ration for labels and tags.

$$ScalingRatio_{adjusted} = ScalingRatio \times \frac{PlantArea_{Perforated}}{PlantArea_{Perforated} - PlantArea_{Blocked} \times 0.75}$$

$$ScalingRatio_{adjusted} = 0.03409 \times \frac{3699 ft^2}{3699 ft^2 - 151 ft^2 \times 0.75} = 0.03517$$

Scaling calculations conservatively ignore the bottom perforated surface of the strainers (plant perforated area is actually greater that 3699 ft^2). This area in reality is still available for flow and debris adherence. This scaling factor was used to scale both flow rate and debris quantities.

NRC RAI 16:
Please identify the distance from the strainer at which debris was added to the test flume and justify the conservatism of this distance based on the transport analysis results for blowdown, washdown, and pool-fill transport. Please specifically discuss consideration of the debris addition in the head loss testing for the fraction of paint chips and other containment debris that would have the potential to wash down onto the strainers from upper containment elevations, and would thus not have to climb over the suction plenum to reach the strainer surface.

WF3 Response 16:
All but one break are at a significant distance from the sump. For the S7 break, which is closest to the sump, a concrete wall separates blowdown from sump. Wash down would only come from Containment Spray in a very limited area over the sump; see Figure 16-1. Transport fractions are based on all debris starting on containment floor at the break location. The top of the Waterford 3 strainers are solid such that debris falling directly on the strainer will not block flow.

For testing performed in June – July 2010, a sparger system was installed on the return line and resided against the back wall of the tank to aid in the suspension of the debris within the water. A mechanical mixer was also installed inside the tank in the corner opposite the strainer module. All debris loads were added over the mixer. For all tests, all debris was added at the side of the tank adjacent to the pump suction, away from the simulated containment floor and walls. This allowed for even and representative debris bed accumulation on the test strainer module. The debris was added in a controlled manner as to not disturb the debris bed through unnecessary turbulence. Along with these methods of debris agitation manual stirring was used when necessary to re-suspend the debris which had not reached the strainer. Manual stirring was done carefully as to not disturb the debris bed and were noted in the test logs.

For thin bed test, the full particulate and microporous debris load were added to begin testing. After an initial 1/8" layer of fiber was added, batches of fiber were added in 1/8" equivalent bed thicknesses. Thin-bed formation was observed visually along with head loss and turbidity measurement. After the final fiber addition met the steady head loss criteria, chemical precipitates were added in 1/3 batch increments. The head loss stabilization criterion was reached after each addition of chemical precipitates prior to the subsequent chemical precipitate addition.

For the full loads and additional margin test, separate fiber and particulate/microporous debris mixes were added incrementally to the tank. The fiber to particulate mass ratio in the tank was maintained constant to provide homogenous debris bed accumulation. Chemical precipitates were added after the head loss of the last addition of non-chemical debris met the head loss stabilization criteria. Chemical precipitates were added in 1/3 batch increments. The head loss stabilization criterion was met after each addition of chemical precipitates prior to the subsequent chemical precipitate addition.

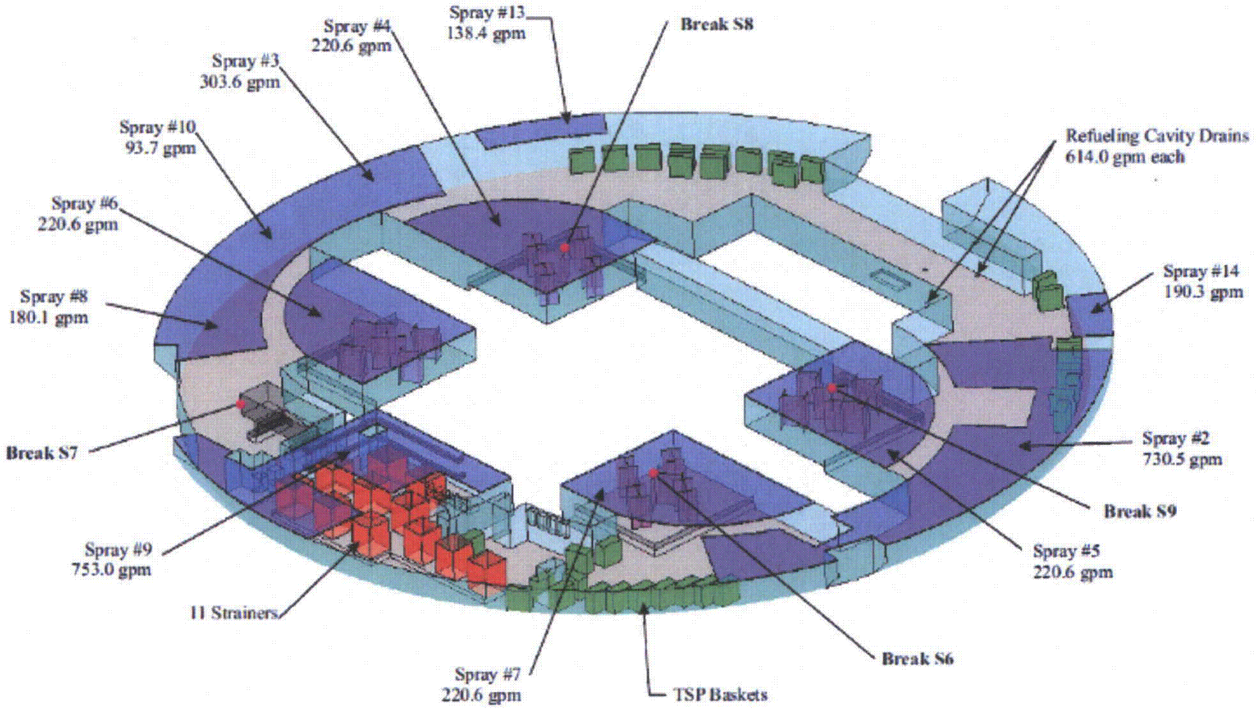


Figure 16-1: Containment Spray Distribution to Safety Injection Sump

NRC RAI 17:
Please describe how the potential for debris transport in the vicinity of the strainer through floatation was considered in the head loss tests for Waterford 3.

WF3 Response 17:
The only debris types with potential floatation concerns are closed cell type materials (i.e. foam) that would never be saturated by water, pieces of high density fiberglass (i.e. Temp-Mat or mineral wool) that may not be saturated with water for an extended period of time, and jacketed low density fiberglass since air may be trapped by undamaged jacketing; (note Waterford 3 does not have closed cell materials or high density fiberglass). Small and large pieces of low density Nukon and MEI fiberglass would be quickly saturated by the hot water in the containment pool and would sink (see NUREG/CR-2982 and NUREG/CR-6808 – Fiberglass insulation readily absorbs water, particularly hot water, and sinks rapidly (from 20 to 60 min in 50°F water and from 20 to 30 s in 120°F water).

The top of the Waterford 3 strainers are not perforated and remain submerged throughout the event. The Nukon insulation that is jacketed and MEI could fail partially as intact blankets that may trap air and float. Given the size of intact blankets, even if this debris floats, it would be easily snagged and held up by miscellaneous structures (equipment supports, grating, etc.) and would likely not transport to the strainers.

If any intact pieces did transport all the way to the strainers, they would not cause significant blockage since Waterford's strainers are not pit strainers and the worst case scenario is simply that the intact pieces would rest against the lower part of the strainers with flow easily passing around them.

NRC RAI 18:
The October 23, 2008, supplemental response identified on page 59 that the assumptions made about the settling of particulate down to 100 microns in size were benchmarked against NRC-sponsored settling tests. Please identify the NRC-sponsored tests being referenced in this discussion.

WF3 Response 18:
The "NRC-sponsored settling tests" is referring to NUREG/CR-6916, titled "Hydraulic Transport of Coating Debris," Naval Surface Warfare Center, Carderock Division. The particulate settling size for the various materials is based on a force balance that accounts for hydraulic drag, gravity, and hydrostatic forces as prescribed in WCAP-16406-P. The developed relationship is compared (benchmarked) to the data in NUREG/CR-6916 Table 3-2 to demonstrate that the relationship produces conservative results. The data from NUREG/CR-6916 was not used as a basis for any materials settling size or depletion determination. Particulate settling is only analyzed to occur in the reactor lower plenum.

NRC RAI 19:
The NRC staff does not consider the licensee's response (in either supplement) to Open Item 4 from the NRC staff audit report of corrective actions to be sufficient because (1) the initial containment pool flows during fill-up will be chaotic and may distribute debris unevenly to the two sides of containment, independent of the relative flow split during recirculation, particularly for breaks such as S7, and (2) the response did not appear to discuss the definition of the starting point for the transport paths used for computing debris transport fractions that had been requested. Please provide a response to these remaining issues associated with Open Item 4 from the audit report.

WF3 Response 19:
The debris transport analysis assumes that the debris transport begins at the break location. The flow split based on computational fluid dynamics (CFD) models is used to determine what percentage of debris travels to the sump from the east and west sides. A review of the Debris Transport Logic Trees for the S1, S3, S4, S5 and S6 breaks indicates that the flow split assumption has no impact on the total transported percentages; i.e. 100% transport from the break side results in same amount of debris at sump.

For break S7, assuming 100% transport from break side results in 79 ft^3 of debris at the strainers. This debris loading is bounded by other tested breaks both in particulate and fiber quantities. For this reason, the transport analysis for the S7 break has been revised to assume 100% transport.

NRC RAI 20:
The supplemental response dated October 23, 2008, states that 25 percent of small debris is treated as lifting onto the sump strainer for one of the computational fluid dynamics scenarios for which less than 25 percent of the perimeter area around the plenum exceeds the curb lift

velocity metric. The staff does not consider the methodology used to determine this percentage of debris lifting over the plenum to be prototypical or conservative because the flow approaching the strainer would be non-uniform. Specifically, most of the post-LOCA debris would approach the plenum from the high flow velocity channel, and very little debris would approach from stagnant regions experiencing low-velocity flows. Please provide a basis for the percentage of debris that can be lifted over the strainer plenum for this case.

WF3 Response 20:
The subject assumption only applied to the S7 break. No other break has velocities that exceeded the curb lift velocity metrics. As stated in RAI response 19, the transport analysis has been revised to assume 100% transport for the S7 break which eliminates the need for the assumption.

NRC RAI 21:
The head loss testing conducted for Waterford 3 credited debris settlement. However, it was not clear that the densities of the Min-K and Microtherm debris used for testing were prototypical or conservative with respect to the corresponding materials installed in the plant. The supplemental response dated October 23, 2008, indicates that the test debris for Min-K could be from 1.1 to 4.8 times denser than the plant debris, and that the Microtherm test debris could similarly be from 1.2 to 2.9 times denser than the plant debris. Since denser debris would tend to settle faster, please either (1) provide additional information that demonstrates that the densities of the Min-K and Microtherm at Waterford 3 are reasonably close to the densities of the surrogate debris tested or (2) justify that the potential for significantly higher densities of the test debris did not lead to non-prototypical settling during the strainer head loss testing.

WF3 Response 21:
Min-K and Microtherm (microporous insulation) were not observed to settle during June – July 2010 testing. This type of insulation tends to be the most transportable debris that is added to the test flume. Per NEI 04-07, Microtherm has a density of 5 -12 lb/ft^3, and Min-K has a density of 8-16 lb/ft^3. 14.5 lb/ft^3 is greater than the density of Microtherm and it is in the upper range of densities for Min-K. The masses of Microtherm and Min-K used in testing were based on the volume of insulation determined in calculations multiplied by an assumed bounding density to ensure that conservative quantities of test debris were used. The value of "14.5 lb/ft^3" does not describe the density of the test materials, it is merely a bounding density used to convert the volume of debris in the plant to a mass of debris to be added during testing. Min-K used for testing consists solely of the microporous component in an un-fused, minimum particle size form, which results in significantly higher head loss per unit mass than the fiber blanket backing. The fiber blanket backing is conservatively substituted with un-fused microporous material. A maximum of 0.4 ft^3 of Min-K and 4.2 ft^3 of Microtherm is generated.

NRC RAI 22:
The NRC staff does not consider the licensee's response (letter dated February 29, 2008) to Open Item 7 from the NRC staff audit report of corrective actions to have fully addressed the item. Please provide additional information to address the remaining points specified below regarding this open item.

a. *Please provide a technical basis for assuming that plant operators are capable of addressing within 30 minutes the postulated single failure of a low pressure safety injection (LPSI) pump to trip upon the switchover to recirculation. This assumption of 30 minutes to address the single failure significantly affects the determination of debris transport, head loss, and net positive suction head available.*
b. *30 minutes would be sufficient time for about one turnover of the containment pool volume. The licensee noted that, during head loss testing, a significant head loss had not occurred within one pool turnover. Therefore, it concluded that there would be no effect on the strainer head loss from the failure of an LPSI pump to trip. Please consider, in the evaluation, the changes that could occur in the transport of debris to the strainer and higher bed compression that could occur due to higher flow rates through the debris bed.*
c. *The description of the head loss testing that was used to justify debris bed formation requiring more than 30 minutes did not identify whether all of the debris had been added at the beginning of the test or whether a phased addition of debris had been used. If an arbitrary phased debris addition sequence was used, the time-dependence of the measured test head loss may not correspond to the bounding plant condition. Please address if a phased addition of debris or a one-time addition of debris was used to justify debris bed formation.*
d. *The October 23, 2008, supplemental response stated that no tests were run for vortexing-specific assumptions. At the initiation of recirculation, non-uniform flow will occur, with the highest flow rate at the modules nearest to the suction line. It was not clear that the additional flow associated with the single failure of an LPSI pump to stop was bounded by the vortex testing performed for Waterford 3. Please provide the requested clarification.*

WF3 Response 22:
Waterford 3 performed new head loss testing in June – July 2010. Part of this testing included determining the impact of temporarily increased flow from a Low Pressure Safety Injection (LPSI) pump failure to trip. The increased flow test conservatively simulated the clean strainer during a LPSI pump-failure-to-trip condition, which could result in a temporary increased plant ECCS flow rate of 12,120 gpm, which results in a gap flow rate of 12,120 gpm/(11 strainers*16 gaps), or 68.9 gpm/gap. The high flow rate air ingestion test used a flow rate of 598 gpm/6 gaps, which resulted in a flow rate of 99.7 gpm/gap. Since the flow rate per gap in the test strainer was higher than that in the plant during a failed LPSI-trip condition, the bulk strainer approach velocity was also higher in the test than in the plant. No air ingestion was observed during the high flow rate air ingestion test with the strainer submerged, so it is concluded that the submerged clean ECCS strainers will not ingest air if a LPSI pump fails to trip post-LOCA.

Emergency Operating Procedures are in the process of being revised to add contingency actions to the Recirculation Actuation Signal Initiation Criteria. An action currently exists to verify the LPSI pumps have stopped once RAS has occurred. If a pump continues to operate, the initial action will be to take the pump control switch to the STOP position. If this action does not secure the pump then the contingency action being considered is to close the LPSI Flow Control valves and open the Shutdown Cooling Warm-up valve for the operating pump. This action will stop the added flow through the sump and would be performed immediately (<5 min) after closing the pump recirculation isolation valves which is required within 2 minutes of RAS to stop the diversion of inventory from the Safety Injection

Sump. Making this change will provide a technical basis for the amount of increased flow and duration for which it occurs. Stopping the sump flow from the LPSI pump eliminates the adverse effects on debris transport and bed formation while providing the pump with a recirculation path minimizes the potential for pump damage. After the valves are re-aligned, an Operator would be dispatched to the pump switchgear to attempt locally stopping the pump.

Commitment 2: Revise Emergency Operating Procedures to include contingency actions for a Low Pressure Safety Injection pump failing to trip on Recirculation Actuation Signal.

D. Head Loss and Vortexing

NRC RAI 23:
Please provide a general description of the emergency core cooling system (ECCS) strainer head loss testing conducted after the Waterford 3 audit, including the scope of the test program, a general description of the overall concept of how the testing addressed the audit issues, the location of the testing, and other relevant issues associated with the broad test program. Adequate details on the test procedures are necessary for the NRC staff to reach conclusions regarding their adequacy. Please include the following information:

a. *description of test facility*
b. *general procedure for conducting the test*
c. *physical arrangement of the strainer within the pool including any dividers or flow diverters*
d. *location of the return header*
e. *location of the stirrers, if used*
f. *scaling parameters and methodology (for sector and module tests)*
g. *total debris amounts (each debris constituent) and basis for the amount*
h. *flow rates*
i. *whether debris settlement was allowed*
j. *whether flow sweeps were completed to search for bore holes*
k. *debris amounts, including chemical debris*
l. *description and purpose of each test case*
m. *plots of the limiting test cases including annotation of significant events during the testing*
n. *comparison and evaluation of pre and post-audit test results (clearly identify pre-and post-audit tests).*

WF3 Response 23:
a. Waterford 3 performed new head loss testing in June – July 2010 at the Alion facility in Warrenville, IL. The test methodology was similar to that already witnessed by NRC staff members and documented in Trip Report ML090500230. A photograph of the test tank and test article is included below as Figure 23-1.

Figure 23-1 – Waterford 3 Test Strainer in Test Tank

b. The general test procedure was similar to that documented in the trip report. The general sequence of each test was as follows:
   1. The tank was verified clean.
   2. The chemical precipitates were prepared in a separate tank following the recipe prescribed in WCAP-16530, and precipitate settling volumes verified.
   3. Fibrous debris was prepared in accordançe with the Alion Debris Preparation Procedure, and particulate debris quantities were carefully weighed out and labeled.
   4. The tank was filled with tap water and maintained between 75 °F – 85 °F.
   5. The pump was turned on, and clean head loss flow sweeps were performed.
   6. The pump flow rate was set to the test flow rate, the agitator was switched on, and debris was added slowly to the agitated area of the test tank (left side of Figure 23-1)
   7. For the thin bed test (WF3-TB), all particulate debris was introduced first into test tank. Next 1/8" equivalent bed thickness fibrous debris was batched into tank, until full screen coverage was observed. For the full-load (WF3-FL) and additional margin (WF3-AM) tests, the total non-chemical debris load was introduced slowly in approximately 25% of the total load increments. Fiber and particulate debris were introduced separately but simultaneously. The fiber to particulate mass ratio of each increment was approximately constant. WCAP precipitates were batched into tank after stabilized head loss was achieved following the addition of the final non-chemical debris batch.
   8. Every effort was made to ensure debris was transported to the strainer, including mechanical and manual agitation of settled debris.
   9. After the final head loss stability criteria were achieved, flow sweeps were conducted to measure the laminar/turbulent head loss distribution.
   10. Strainer head loss testing was performed in accordance with the applicable test procedure and the Test Matrices described in the Test Plan.
   11. Test data and logs were recorded and maintained for post-test analysis.
   12. The tank was drained and cleaned.

c. A small-scale plant model with one sump strainer module was created in the test pool. The model included the plenum and one test module with a width and length matching the plant strainer design but with 7 disks rather than the plant design of 17. An isometric drawing of the layout is included as Figure 23-2.

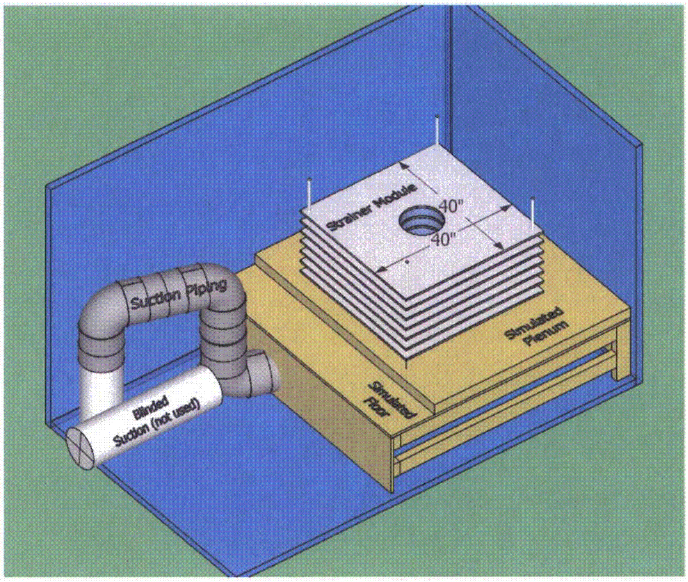


Figure 23-2: Isometric Layout of Test Tank and Strainer (Return header is not shown)

d. The return header was positioned along the bottom rear corner, and the flow directed along the floor such that the proper turbulence levels were created in the tank and settling was prevented.
e. Stirrers were positioned and adjusted to maintain enough turbulence to suspend all debris without affecting debris bed formation or inducing bed shift (See Figure 23-1). Manual stirring was utilized when required.
f. No sector testing was performed. Module test results were scaled using the Alion methodology to adjust for temperature-based viscosity effects. The Waterford 3 test strainer module replicates all hydraulic dimensions of the Waterford 3 plant strainer except for number of strainer gaps. Therefore, debris and flow rate scaling was performed without adjustments due to net flow area or strainer geometry since these were accounted for in the test article – scaling was able to be performed based only on the numbers of strainer gaps and accounting for the sacrificial strainer area due to labels and tags. Note that although scaling ratio is based on the number of strainer gaps, the "gap scaling ratio" is equivalent to the ratio of test and plant strainer perforated areas. The scaling equation is provided below:

$$Debris_{Test} = ScalingRatio_{Adjusted} \times Debris_{Plant} = 0.03517 \times Debris_{Plant}$$

g. Test debris amounts were proportional to plant debris amounts based on the ratio of the test screen perforated surface area to the installed sump screen perforated surface area. The thin-bed test, test WF3-TB, used various thickness of fiber to test for thin-bed effect, from 1/8th in. to the maximum fiber thickness. Test WF3-FL was the full-load debris test. Test WF3-AM was a full-load debris test using 10% additional fiber. Table 23-1 lists the debris types, surrogates, and the plant quantities represented during testing.

Debris Type	Debris Name	Test Debris Surrogate	Unit	WF3-TB	WF3-FL	WF3-AM
Particulate	Min-K	Min-K (pulverized powder)	[ft^3]	0.4	0.4	0.4
	Microtherm	Microtherm (pulverized powder)	[ft^3]	4.2	4.2	4.2
	Qualified Coatings	10-micron Silicon Carbide	[ft^3]	13.5	13.5	13.5
	Unqualified Coatings		[ft^3]	13.1	13.1	13.1
	Latent Particulate	Dirt and Dust	[ft^3]	1.29	1.29	1.29
Fiber	Nukon	Nukon (fines)	[ft^3]	253.1	253.1	281.5
	Transco MEI					
	Additional Fiber					
	Latent Fiber		[ft^3]	37.5	37.5	37.5
Chemical Effects	Calcium Phosphate	Calcium Phosphate Surrogate	[lb]	111.6	111.6	127.9
	Sodium Aluminum Silicate	Sodium Aluminum Silicate Surrogate	[lb]	195.1	195.1	198.6

Table 23-1: Tested Debris Types and Represented Plant Quantities

h. The flow rate of the module was set to 228 gpm, such that the perforated approach velocity of the module conservatively bounded the perforated approach velocity of the plant strainer. Test circumscribed velocity was also considered so that it matched or exceeded the plant circumscribed velocity.
i. Debris settlement was not credited in testing.
j. Flow sweeps were performed before debris addition and after all debris had been added and the head loss had stabilized.
k. Fiber and chemical debris were scaled as stated in item (g) above. The quantity of chemical debris was based on plant specific WCAP-16530 analysis.
l. Three test cases were run; one thin bed test and two full load tests in accordance with the NRC March 2008 guidance as described in item (b.7) above. One full load test was done with design basis loading and the second was done with additional 10% fiber loading for margin.
m. Plots for the limiting test cases are presented below as Figures 23-3 through 23-5.
n. This item was determined on the March 8, 2010 NRC/Waterford 3 call as no longer being required.

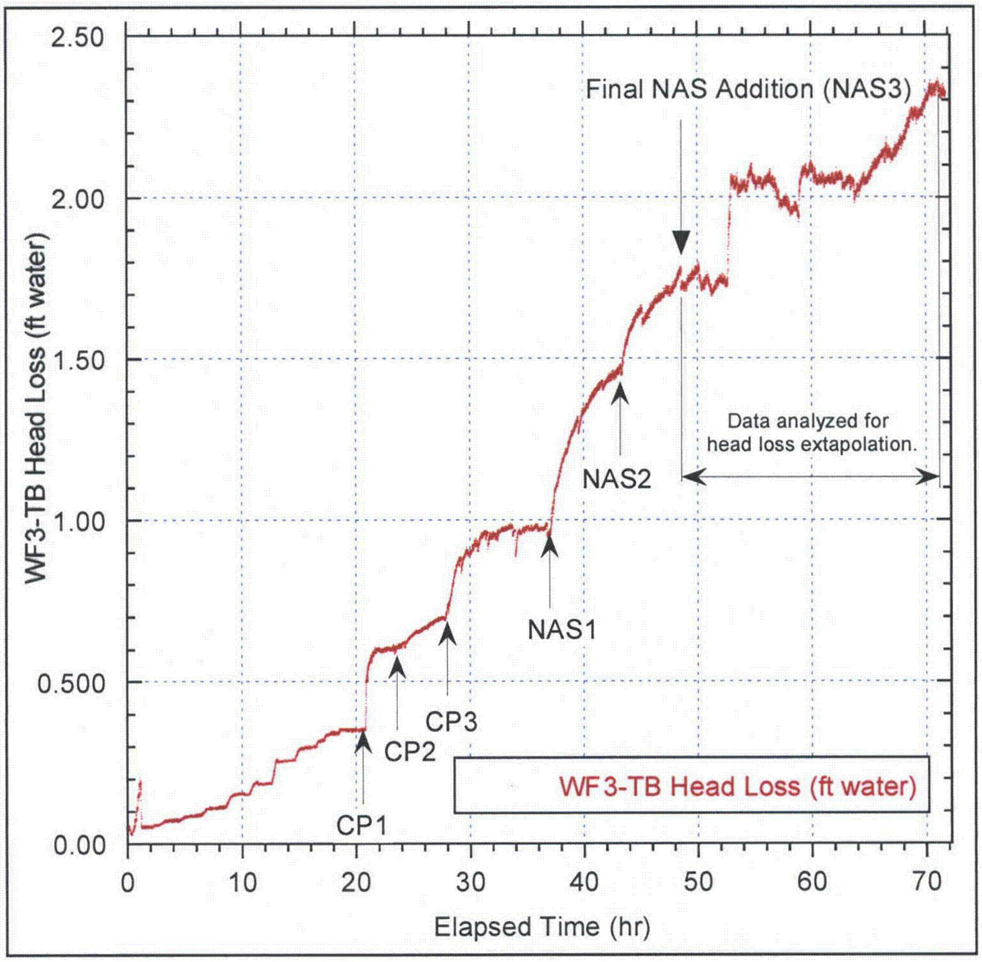


Figure 23-3: Thin Best Test Raw Data Plot

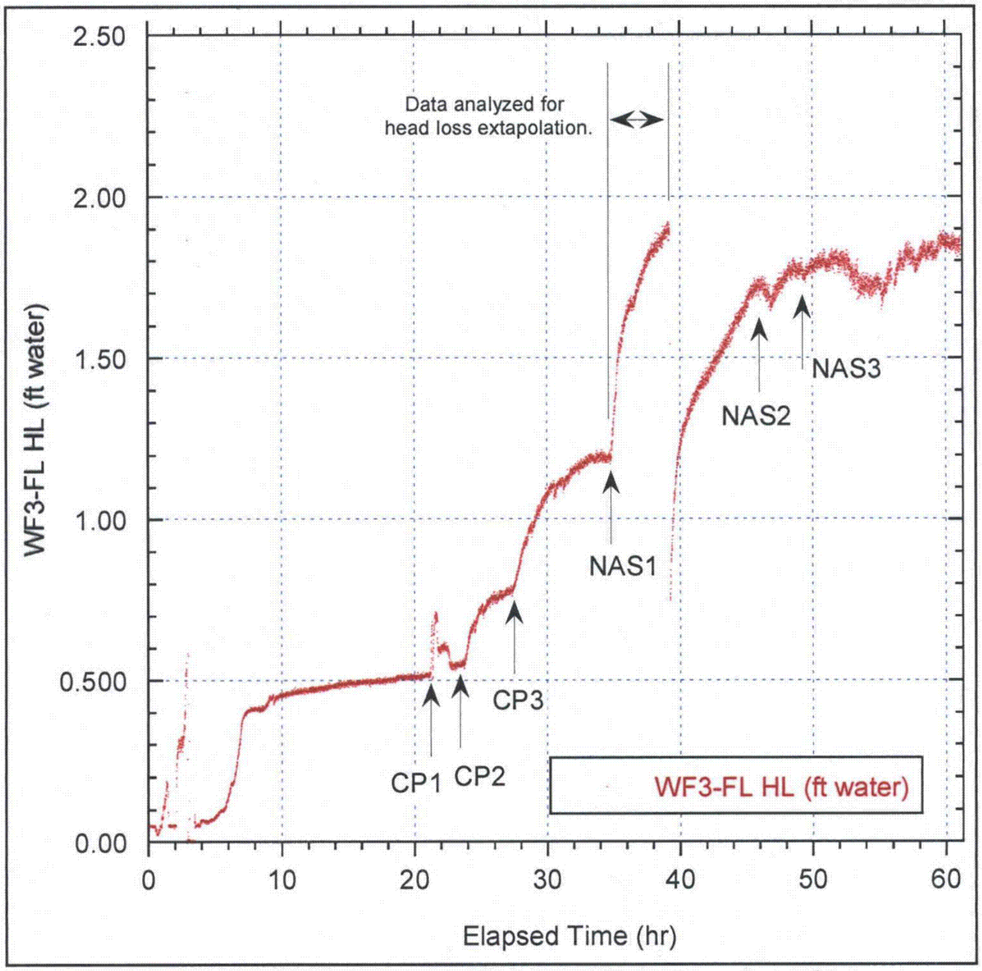


Figure 23-4: Design Basis Full Load Test Raw Data Plot

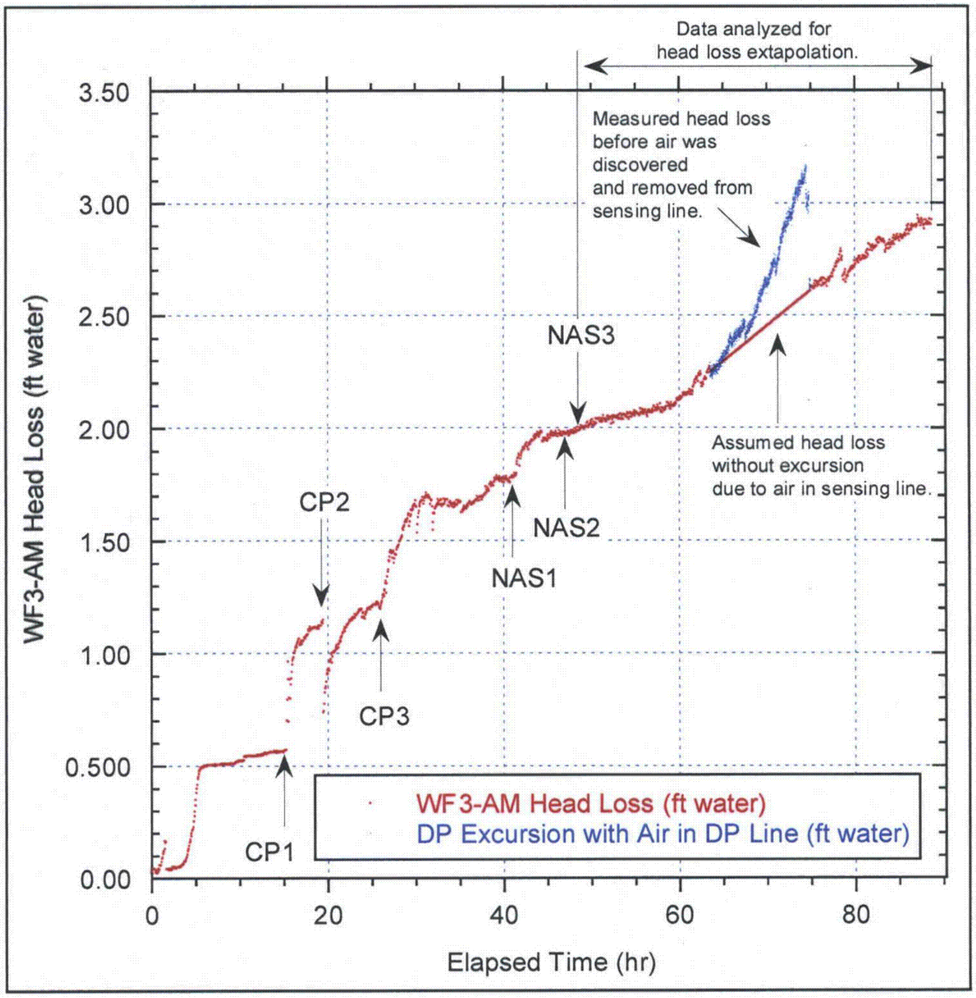


Figure 23-5: Additional Margin Full Load Test Raw Data Plot

<u>NRC RAI 24:</u>
Please provide the documentation of fiber size distribution used for post-audit head loss testing and how this compares to the fiber size distribution predicted to arrive at the strainer by the transport evaluation. The supplemental response dated October 23, 2008, stated that fiber used in the testing was shredded five times. Please provide a qualitative size distribution for the fibrous debris used in the testing. Please justify that the methodology used to create the debris resulted in acceptable debris sizing.

<u>WF3 Response 24:</u>
Testing performed in June - July 2010 used the same methods for debris preparation used to prepare debris for the Alion testing witnessed by the NRC and documented in trip Report ML090500230.

Alion debris preparation procedure ALION-SPP-LAB-2352-22 was used. This procedure produces the required size distribution and fiber fines (NUREG/CR-6224 Classes 1-3) that are easily transportable and readily disperse in the testing fluid environment. All fiber fines were double-shredded with a leaf shredder and boiled for 10 minutes. Fiber fines, as described in the debris preparation procedure, were further processed by adding 4 gallons of water to ¼ lb of fiber and beating with a paint stirrer for 4 minutes immediately prior to debris addition to the test tank. A photo of the prepared fiber taken during testing is provided in Figure 24-1.

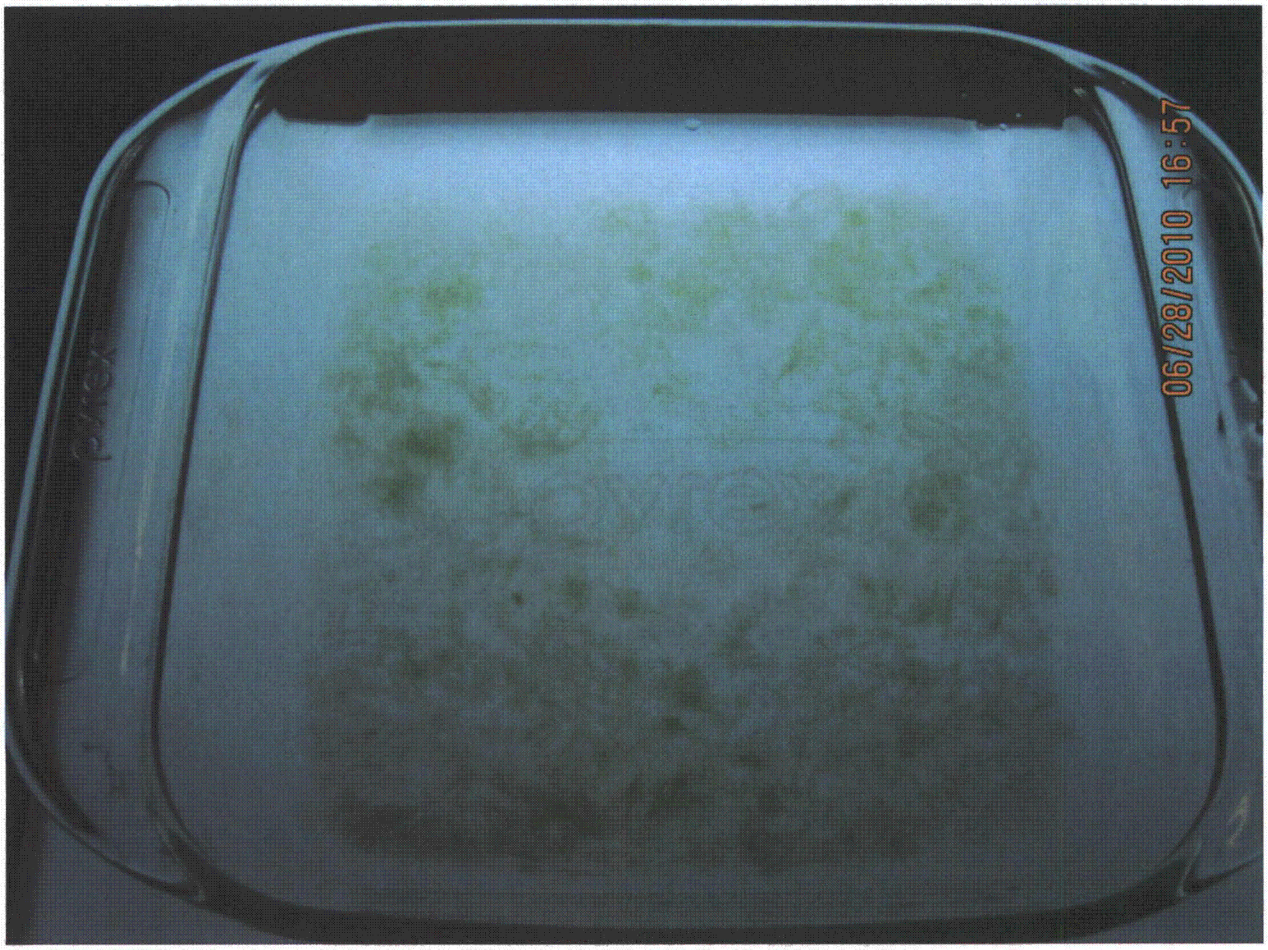


Figure 24-1: Nukon fines over the light box in an 8" x 8" Pyrex dish

<u>NRC RAI 25:</u>

Please verify, for thin-bed testing and testing that allowed near-field settling, that all fine fiber was added prior to the addition of coarser fibrous debris. Waterford 3 has predicted sufficient fine fibrous debris to be created, such that all thin-bed testing should be conducted with only fine fibrous debris to establish a bounding condition, consistent with the "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing," dated March 28, 2008 (ADAMS Accession No. ML080230038), unless the licensee can justify otherwise. This item is associated with Open Item 8 of the NRC staff audit report of corrective actions, which applied to both thin-bed and higher debris load testing.

WF3 Response 25:
Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance and did not credit near field settling. The general test protocols have been observed by the NRC Staff as documented in Trip Report ML090500230. The fiber debris size distribution for the Thin Bed test was "fines" NUREG/CR-6224 Classes 1-3.

NRC RAI 26:
Open Item 10 from the NRC staff audit report of corrective actions stated that adding all debris prior to starting the recirculation pump could result in agglomeration and excessive settling, and to the formation of a bed that is less dense than one formed by a more gradual arrival of debris. The licensee's supplemental responses did not provide sufficient information for the NRC staff to conclude whether this concern, and others related to the potential for nonconservative debris settling and agglomeration, applied to the post-audit testing. Please provide the following information regarding debris additions during the post-audit testing, including their impact on agglomeration and settling of debris:

a. *fibrous concentration during addition and method of addition to flume that justifies that debris was not agglomerated*
b. *location(s) of debris additions*
c. *amount of each debris constituent in each batch including chemical batches*
d. *order of debris batch addition to the test*
e. *time between batches*
f. *whether the recirculation pump was running during debris additions*

WF3 Response 26:
Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance and did not credit near field settling. The general test protocols have been observed by the NRC Staff as documented in Trip Report ML090500230.

Fiber was placed in buckets with sufficient water to create a thin slurry. Fiber with water was mixed using a paint stirrer until no agglomeration or clumping was observed. For fiber, this slurry consisted of approximately ¼ lb of fiber per 4 gallons of water. A similar protocol was followed for particulates. The particulate slurry consisted of approximately 10 lbs of particulate per 3 gallons of water for the coatings and latent particulate surrogate and 3 lbs of particulate per 3 gallons of water for the Min-K and Microtherm.

Debris was introduced into the tank in an area of high velocities and turbulence near the pump return line. Adjustable tank internal mixing was added to an area of low velocities opposite to the pump return line. Extra care was exercised to prevent turbulence from the return flow and internal mixing from disturbing the debris deposition. Fibrous debris addition rate was limited so that the fibrous debris concentration in the test tank never exceeded the predicted worst-case initial post-LOCA fiber concentration in the Waterford 3 sump. Debris was added to the test tank at a rate that did not result in non-representative debris concentration and agglomeration.

During thin-bed testing, particulate debris was added prior to fiber addition. During full-load and additional margin testing, particulate and fiber debris were added separately but simultaneously.

The chemical precipitates were prepared in a separate tank following the recipe prescribed in WCAP-16530. Chemical precipitates were verified to ensure that the appropriate settling velocity had been achieved no more than 24 hours prior to use. They were added after the head loss of the last addition of non-chemical debris met the head loss stabilization criteria. Each chemical precipitate was added separately in three batches with head loss stabilization criteria being met between each batch. Calcium Phosphate was added first followed by Sodium Aluminum Silicate.

The recirculation pump ran continuously during testing.

NRC RAI 27:

Please provide and justify the method for extrapolation of test results to mission times for the post-audit tests. Note that the tests reviewed during the audit were found to have acceptable final values. Therefore, if the same approach was used during the later testing, and similar head loss trends at the end of the test were observed, a statement to that effect will suffice.

WF3 Response 27:

Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance and did not credit near field settling. The general test protocols have been observed by the NRC Staff as documented in Trip Report ML090500230.

The Alion test termination criterion allows for an increase of less than 1% over a one hour interval at the completion of the test, resulting in test durations of less than 30 days. A natural logarithmic decay expression is fit to the end of test data (from final debris addition to termination criteria met), then a positive head loss offset is added to the expression to bound all measured head loss for that particular test. A sample of the logarithmic fit to test data is included as Figure 27-1.

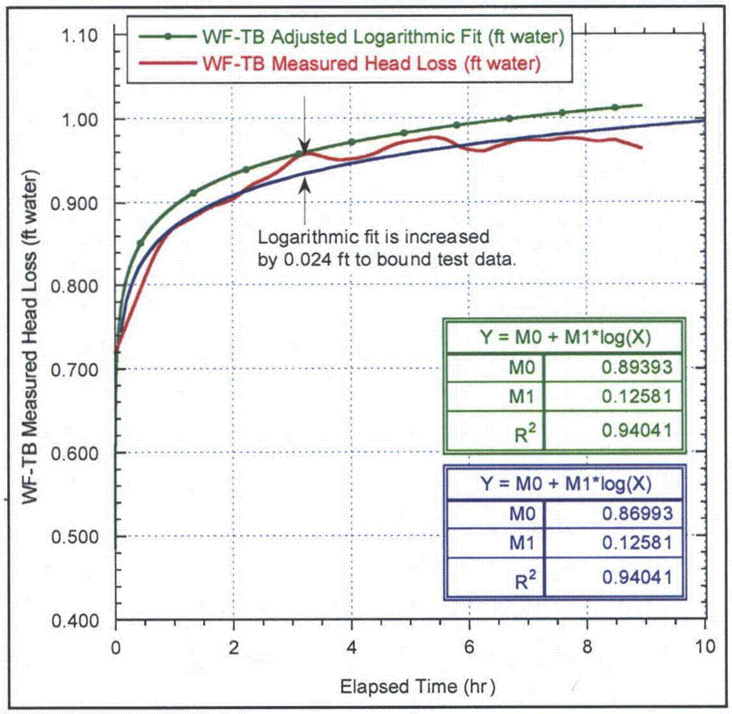


Figure 27-1: Thin Bed Test Smoothed Data and Logarithmic Curve Fit

Using the resulting logarithmic curve fit expression; the head loss at 30-days (720 hours) was then extrapolated. In one case where the maximum measured head loss was not at the end of the test (WF3-FL), the data prior to the maximum measured head loss was used rather than the end of test data to ensure that the extrapolated head loss was conservative.

NRC RAI 28:
Please provide and justify the test termination criteria. Please provide data to show that the updated testing met these criteria. Note that the testing conducted prior to the audit was found to be satisfactory in this area. Therefore, if the same approach was used during the later testing, and similar head loss trends at the end of the test were observed, a statement to that effect will suffice.

WF3 Response 28:
Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. The test was terminated after all chemical and non-chemical debris had been added to the test tank and the following criteria were met.

The final debris addition Subtest prior to the addition of chemical debris, and the final chemical debris addition Subtest prior to the end of test flow sweep Subtest points required the most stringent stabilization criteria. These Subtests required at least 10 pool turnovers after debris addition and the following stabilization criteria:

- The head loss stabilization criteria are :
    - Measured Head Loss > 2 feet: <1% change in head loss/hr
    - Measured Head Loss < 2 feet: <0.25" change in head loss/hr

- Additionally, one of the following three requirements had to be met:
    - Decreasing head loss for at least one hour
    - No increase in head loss for at least one hour
    - Decreasing rate of increase in head loss over three hours

NRC RAI 29:
Please provide the methodology used to revise the plenum portion of the clean strainer head loss to 0.063 feet (ft) from 0.41 ft.

WF3 Response 29:
During an owner's review of the vendor prepared plenum head loss calculation it was determined that the analysis used an incorrect equation that did not accurately reflect the velocity in the rectangular plenum. When the correct equation was selected, head loss reduced from 0.41 ft to 0.063 ft. Standard Crane TP-410 head loss methodology was used.

NRC RAI 30:
The NRC staff audit found that stirring, in combination with the inadequate preparation of fibrous debris, may have affected the test results non-prototypically. Please provide information as to whether stirring was used during post-audit testing and how it was employed, including the duration of the stirring. If stirring was used, provide justification that the testing was conducted in a manner that would prevent non-prototypical debris transport. Also, please justify that stirring did not prevent debris from collecting naturally on the strainer.

WF3 Response 30:
Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance and did not credit near field settling. The general test protocols have been observed by the NRC Staff as documented in Trip Report ML090500230. Stirrers were positioned and adjusted to maintain enough turbulence to suspend all debris without affecting debris bed formation or inducing bed shift.

NRC RAI 31:
Pre-audit thin-bed testing was based on a break that resulted in much lower amounts of particulate debris than other identified breaks. The NRC staffs March 28, 2008, head loss and vortexing review guidance states that thin-bed testing should identify whether the full-particulate load, with varying fibrous loads, will result in the limiting head loss for the plant. The guidance also states that thin-bed testing with less than the full-particulate load is not generally considered to be conservative. Please provide documentation that shows that the updated thin-bed testing was prototypical or conservative.

WF3 Response 31:
Waterford 3 performed new head loss and chemical effects testing in June – July 2010 using the Alion test protocols. This testing was performed in accordance with the NRC March 28, 2008 head loss testing guidance and did not credit near field settling. The general test protocols have been observed by the NRC Staff as documented in Trip Report

ML090500230. Thin bed testing was performed utilizing a bounding particulate debris load with varying amounts of fiber and chemical loadings.

NRC RAI 32:
The supplemental response dated October 23, 2008, included a scaling equation that included scaling for debris bed thickness and flow velocity, as well as temperature. The scaling of results to different flow velocities or debris bed thicknesses may not follow the scaling equation presented in the supplemental response. Please provide details for any scaling to different velocities or debris bed thicknesses including the test conditions and results, and the plant condition to which it is being scaled. Please provide the same information for any temperature scaling conducted.

WF3 Response 32:
Waterford 3 new head loss and chemical effects testing performed in June – July 2010 utilized the Alion scaling methodology. This methodology does not scale based on debris bed thickness. The methodology does account for both laminar and turbulent flow regimes while scaling based on temperature based viscosity effects. The scaling equation used is the following:

$$\Delta H_2 = \Delta H_1 \left[R_L \frac{\mu_2}{\mu_1} + R_T \frac{\rho_2}{\rho_1} \right]$$

Where:

R_L = ratio of laminar head loss to total head loss
μ= dynamic viscosity at each temperature (lbm/ft/sec)
R_T = ratio of turbulent head loss to total head loss
ρ = density at each temperature (lbm/ft^3)
ΔH_1 = Extrapolated long-term head loss at test temperature (T_1)
ΔH_2 = Extrapolated long-term head loss at plant temperature (T_2)

To determine the laminar and turbulent head loss fractions, a flow sweep was conducted at the end of each test to measure the dependence of head loss on approach velocity. The collected data was plotted and a binomial expression fit to the data. Using this binomial expression, the laminar and turbulent head loss component ratios were calculated and used in the equation above to extrapolate test results to plant sump temperatures.

Debris bed shifts occurred during testing, and this was accounted for when extrapolating head loss based on temperature. To ensure that the final extrapolated plant head loss is conservative, head loss was not extrapolated below the highest measured head loss prior to a debris bed shift. This ensures that the head loss required to produce the bed shift is considered in the strainer design.

NRC RAI 33:
The supplemental response dated October 23, 2008, stated that flashing at the strainer would not occur because the strainer submergence is 8 inches and the maximum head loss is about 6 inches. This is true for a large-break LOCA, but does not address a small-break

LOCA, which has a bounding submergence of about 2 inches. Please provide an evaluation for flashing during a small-break LOCA at the most limiting condition. This may require an evaluation of head loss versus submergence over time or credit for accident-generated pressure.

WF3 Response 33:
Credit for 1 psi of containment overpressure will provide > 2 ft flashing margin when submergence is less than the bounding head loss. Sump temperature will reach 210 °F at about 2.2 hrs after Recirculation Actuation Signal and exceed 210 °F for only about 11 hrs during the event. The maximum temperature profile is based on; (1) 1 of 2 Containment Spray Trains operating, (2) 1 of 4 Containment Fan Coolers operating, and (3) minimum Safety Injection flow. Waterford 3 Technical Specifications require containment pressure to be maintained between 14.275 psia and about 1 psig (27 inches water).

When expected containment pressure is compared to the saturation pressure of the sump fluid throughout the duration of an event it can be seen that adequate margin exists to support the 1 psi overpressure credit. Two cases are presented below. Figure 33-1 shows the comparison for the maximum sump temperature evaluation. Figure 33-2 shows the comparison for the minimum sump temperature evaluation.

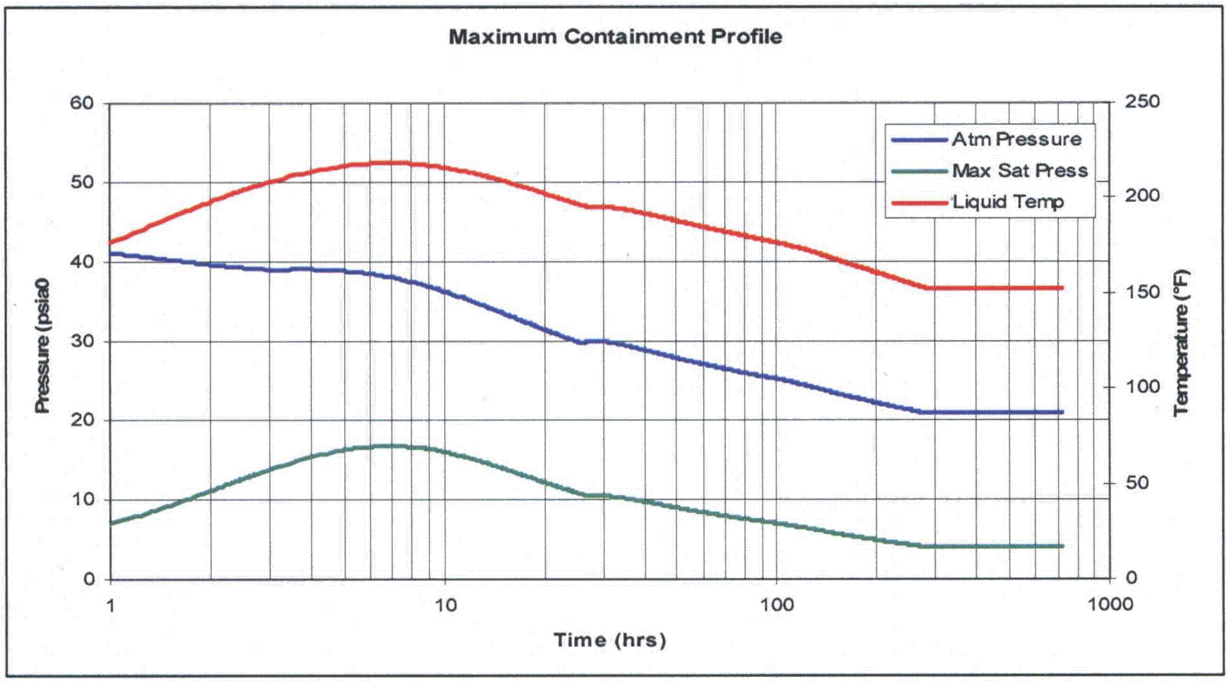


Figure 33-1: Containment Pressure Profile Based on Maximum Temperature

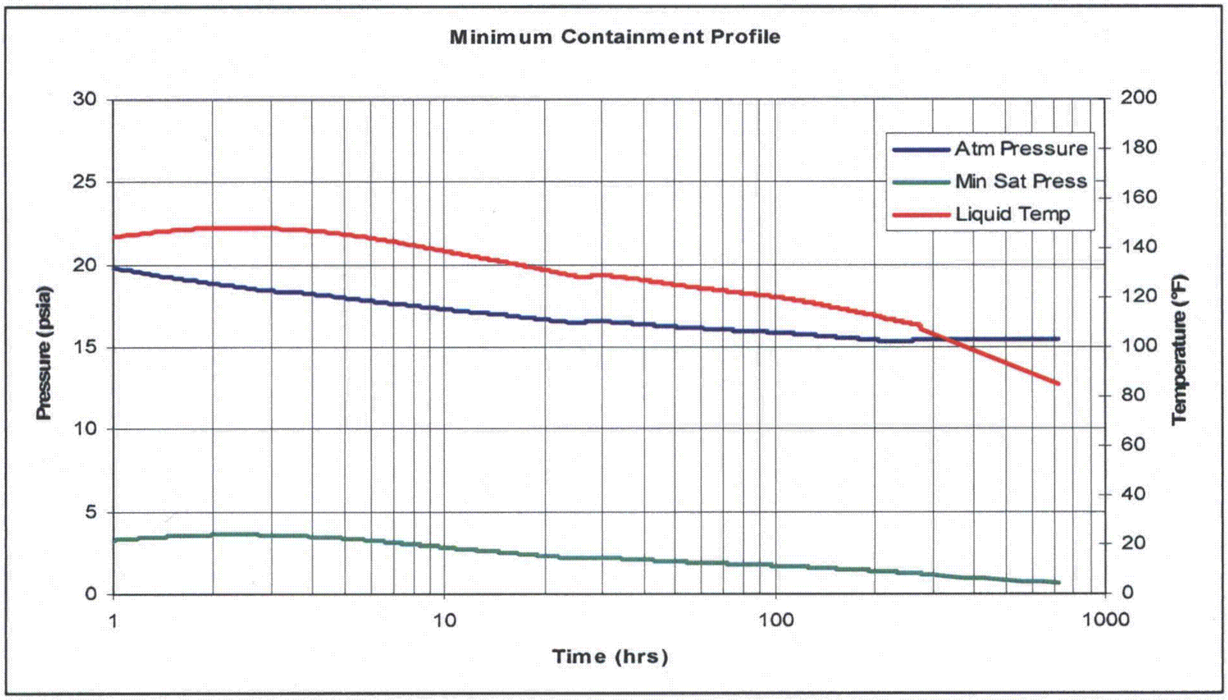


Figure 33-1: Containment Pressure Profile Based on Minimum Temperature

NRC RAI 33a:

Please provide an evaluation of gas evolution downstream of the strainer that could reach the pump suction. Please provide the percentage of evolved gas estimated at the pump inlet. Evaluate the effects of any potential gas ingestion to the pumps taking suction from the sump as described in RG 1.82, Appendix A. The staff is concerned that any gasses that are stripped from the fluid as it passes through the strainer could collect within the strainer and eventually transport to the pump suction as larger air pockets. In addition, the staff has not received information that would characterize the re-dissolution of air or gas as the static head on the fluid increases as it flows to the pumps suction. If re-dissolution of air is credited, please provide an evaluation of the variables that could affect the re-dissolution.

WF3 Response 33a:

Based on Henry's Law, the amount of air dissolved in a fluid is proportional with the pressure of the system. Therefore, the amount of air that can come out of solution is proportional to the pressure drop across the strainer. The table below provides solubility values for air in water at atmospheric pressure for two temperatures.

Temperature °F (°C)	68 (20)	212 (100)
by volume air in water	0.020	0.012

*Marks' Standard Handbook for Mechanical Engineers, Eighth Edition

Using the pressure difference across the strainer the fraction of air stripped from the fluid as it passes through the strainer is determined. This method conservatively assumes that the water entering the strainer is fully saturated with air. A value is calculated for both low and high temperature.

Based on head loss testing, the head loss across the strainer is 3.95 ft at 90 °F and 2.09 ft at 210 °F.

Low Temperature
3.95 ft ~ 0.12 atm
Void fraction = pressure drop * solubility = 0.12 * 0.020 = 0.0024 = 0.24 % by volume
High Temperature
2.09 ft ~ 0.06 atm
Void fraction = pressure drop * solubility = 0.06 * 0.012 = 0.0007 = 0.07 % by volume

These values are applicable at the top elevation of the strainer. As the flow stream leaves the strainers it travels downward where it experiences an increase in pressure due to the elevation difference. This increase in pressure is greater than the maximum head loss and would promote some of the air re-dissolving back into the water. The void size would also experience a reduction in size due to compression.

Conservatively neglecting the re-dissolution of air, the void fraction at the pump suction can be calculated using the ideal gas law.

$P_1V_1 = P_2V_2$; therefore $V_2 = P_1V_1/P_2$
P_1 = 14.7 psia * 2.31 ft/psi = 34 ft
$P_2 = P_1$ + 30 ft = 64 ft (elevation difference from water surface to pump inlet is ~30ft)
$V_2 = V_1$* 34 ft / 64 ft

Low Temperature V_2 = 0.24* 34 ft / 64 ft = 0.13 % by volume
High Temperature V_2 = 0.07* 34 ft / 64 ft = 0.04 % by volume

Using the relationship from Regulatory Guide 1.82, it can be seen how the void fraction will affect required net positive suction head.

$NPSH_{required'} = NPSH_{required} * (1+0.5*\alpha)$ where α is the air ingestion rate in percent by volume
Highest $NPSH_{required}$ for any ECCS pump operating at runout conditions is 21.765 ft

Low Temperature
21.765 ft * (1 + 0.5 * 0.13%) = 23.18 ft or an increase of 1.42 ft

High Temperature
21.765 ft * (1 + 0.5 * 0.04%) = 22.2 ft or an increase of 0.44 ft

As the sump fluid decreases in temperature, the NPSH margin increases significantly due to subcooling. At low temperatures, ample margin exists (>10 ft) to compensate for the slight increase in NPSH required. Conservatively neglecting subcooling at the maximum temperatures, the NPSH margin would only be ~ 0.5 ft. This value is greater than the 0.44 ft calculated increase in NPSH required. As stated in the response to RAI 33, at least 1 psi of containment overpressure will exist at all time during a Loss of Coolant Accident. This 1 psi of over pressure would create additional NPSH margin of at least 2.3 ft at elevated temperatures.

Based on the above discussion and conservative evaluation, deaeration of the water is not a problem for any temperatures and pressures for Waterford 3

NRC RAI 34:

In the head loss table on page 32 of the supplemental response dated October 23, 2008, case S7, the pressurizer surge line break is bounding. Page 8 of the supplemental response states that the debris from the S7 break is insignificant. Please provide an evaluation of how the debris generated from the S7 break could result in a higher head loss than a thin bed case from other breaks, considering the much higher particulate debris generation. Based on observations of many strainer head loss tests and theoretical predictions of head loss, the staff believes that a thin-bed test for other break conditions, that would have a comparable amount of fiber plus a significantly larger particulate source term (including microporous insulation), would likely result in higher head losses if testing is conducted in accordance with the existing guidance.

WF3 Response 34:

The S7 test results listed on page 32 of the Supplemental Response, dated 10/23/08, are no longer applicable to Waterford 3 due to refined debris generation and transport calculations. Tests were not run post-audit for S7 as pre-audit testing concluded that S7 was not bounding. The S7 break generates and transports far less fibrous and particulate debris than the other breaks that were evaluated.

Test S7-2S-100-CS ⇒ 100 ft^3 fiber (latent fiber not included)
Test S7-1S-59.2-CS ⇒ 298 ft^3 fiber (latent fiber not included)
Current S7 generation ⇒ 79 ft^3 fiber (latent fiber not included)

Revised debris generation and transport analysis with Reflective Metal Insulation (RMI) covered Steam Generators continues to result in the S7 break producing the smallest debris load transported to the strainers. All testing done in June – July 2010 used a debris load that bounded all breaks.

E. Net Positive Suction Head

NRC RAI 35:

The supplemental response dated October 23, 2008, stated that the minimum water level calculation did not specifically include the potential RCS volume reduction due to cooling of the fluid (part of audit Open Item 13). Instead, this phenomenon was considered to be bounded by the lack of credit allowed for the reduction in RCS level in the steam generators and pressurizer due to flow from the pipe break. It is not clear to the staff that the credit for RCS inventory can be reasonably assumed for all breaks. One example is that a small break near the top of the pressurizer could result in a condition where the loss of inventory from the RCS is eventually made up for and exceeded by incoming flow from the high-pressure safety injection system. In such cases, the RCS could be a net holdup volume, due to the RCS cooldown after the LOCA and/or due to the potential for the ECCS to refill the RCS to a pressurizer level beyond the normal operating condition. Please provide information that *justifies that neglecting RCS shrinkage due to fluid cooling can be offset by the uncredited margin associated with the RCS inventory from the pressurizer and steam generators. The evaluation should determine the magnitude of the sump level change due to RCS cooling and verify that there is adequate RCS spillage to the containment for all breaks that credit the spilled volume, accounting for the concerns discussed above.*

WF3 Response 35:
Calculation MNQ6-4, "Water Levels Inside Containment", has been revised to assume a break location at the top of the pressurizer. The revised calculation also assumes that the Reactor Coolant System cools down from normal operating pressure and temperature (600 °F / 2250 psia) to post LOCA conditions (210 °F / 14.12 psia). To ensure that an adequate water level is maintained for Net Positive Suction Head purposes, two assumptions in the previous revision of the calculation were changed.

The first assumption is that the atmosphere is filled with saturated steam at 260 °F for the duration of the event. Review of Containment Pressure & Temperature analysis show that this value can be reduced to 250 °F and remain conservative. This change provides about 570 ft^3 more water to the sump.

The second assumption is that the Containment Sump does not freely associate thru the floor drainage system with the Safety Injection Sump. The Containment Sump is assumed to fill to an elevation of 7.5 ft Mean Sea Level (MSL) before the Safety injection Sump water level begins to fill. This would only be the case for breaks at the reactor vessel. All other break locations are outside of the Containment Sump. With free association between sumps and a break at the top of the Pressurizer, the resultant sump level is -5.75 ft MSL for a SBLOCA and -5.26 ft MSL for a LBLOCA. For a break at the Reactor Vessel and without free association between sumps, the resultant sump level is -5.53 ft MSL for a SBLOCA and -5.03 ft MSL for a LBLOCA. It is therefore conservative to assume that the sumps freely associate and the break is located at the top of the Pressurizer.

NRC RAI 36:
The sump level calculation assumes that no holdup occurs in the refueling canal. Open Item 16 from the NRC staff audit report of corrective actions requested that the licensee provide information justifying that the drain lines would not block and provide a holdup volume. The evaluation provided in the supplemental response dated October 23, 2008, was based on judgment and lacked technical basis or any information beyond that provided during the audit. Holdup in the refueling canal will affect sump level, and therefore, net positive suction head margin. Waterford 3 has hundreds of cubic feet of fiber as well as miscellaneous debris and other materials. It is not evident that the upper guide structure lift rig and an access ladder (diver stairs) are sufficient to keep larger debris out of the drains for the refueling canal. The supplemental response does not address why large pieces of debris cannot be blown into the upper containment. If such debris ends up in the refueling cavity, it is not evident that temporary floatation, transport by surface currents over the drain, and subsequent soaking with water, can be ruled out. If drain blockage can be ruled out, then please identify whether any water buildup is necessary to create sufficient driving head for flow to occur through the drain for a clean condition. Alternately, if drain blockage cannot be ruled out, then please evaluate the potential holdup in the refueling canal and its effect on

pool water level. Please provide additional information that justifies that the refueling canal drains cannot become fully or partially blocked so that no hold up will occur.

WF3 Response 36:
Five of the seven breaks analyzed for GSI-191 are below the 14 ft. elevation in the containment D-rings that has a top elevation of 62.25 ft. The breaks in the Pressurizer cubicle (S7) and at the reactor (S2) are shielded by physical structures (walls, grating, cavity ring seal) from sending debris in to the upper areas of containment. The 5 breaks in the D-rings would have to project debris larger than 6 inches (drain size) through an obstruction filled D-ring and then over the D-ring wall. The D-rings contain multiple grating platforms and major equipment above the breaks that would prevent debris from traveling upwards. Once the Replacement Steam Generators are installed with RMI insulation, nearly all of the fibrous debris postulated to be generated by a break in a D-ring will be below the significant obstructions. See the Figure 36-1 showing the platforms and major equipment that is above the postulated breaks inside the D-rings.

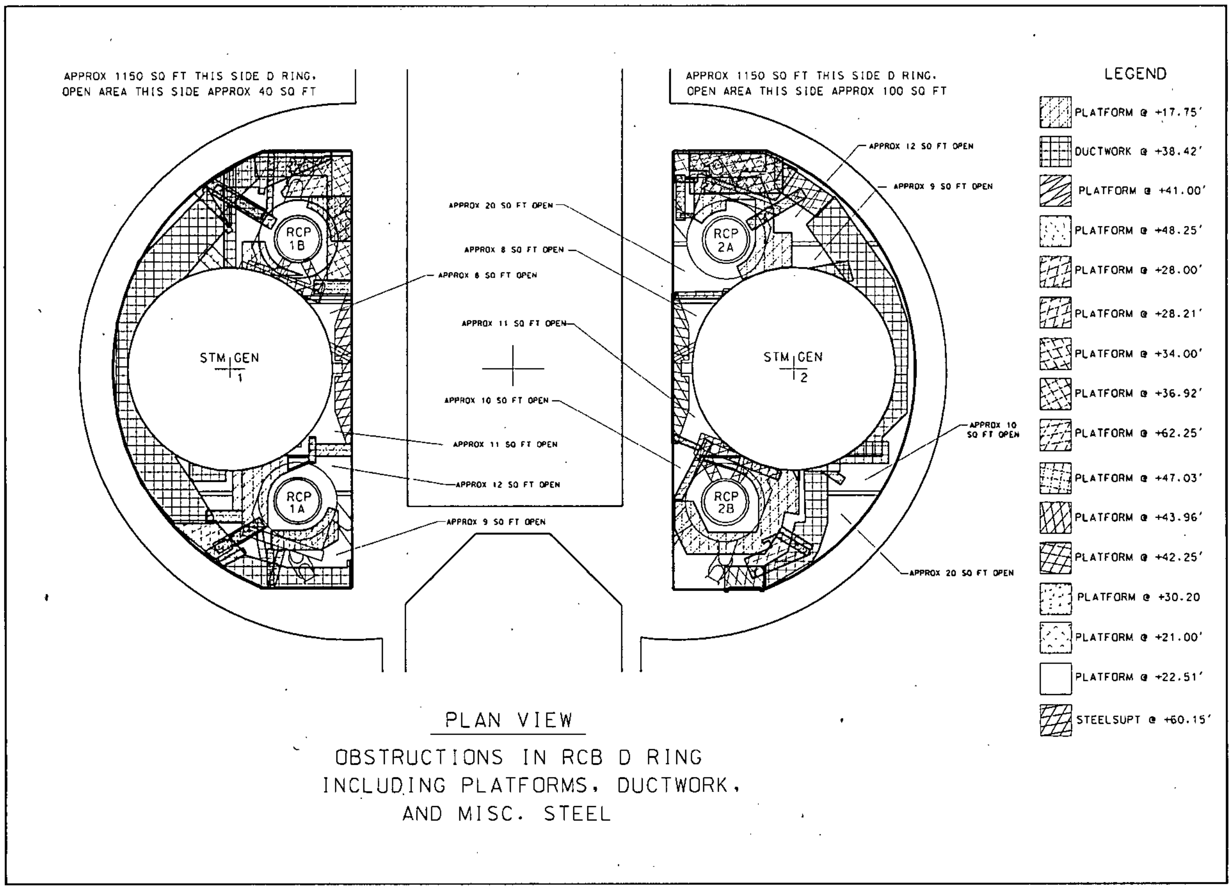


Figure 36-1: Obstructions in D-Rings

Note that this sketch does not include pipe supports, smaller piping, duct supports, or other smaller equipment that will also block this insulation from flying up into the upper areas of containment.

If any debris does exit the D-rings, it would be required to fall on top of the drain. Any debris 6" or larger would not transport in the cavity. Sufficient flow can be achieved through the two 6" drains without requiring any measurable water level in the cavity. One of the drains is near the north wall and below a set of stairs used to access the upper guide structure lift rig. The other drain is near the end of the stairs. Directly to the west of both drains is the upper guide structure lift rig. These obstructions would hamper the transport of debris in the cavity and help shield the drains from falling debris.

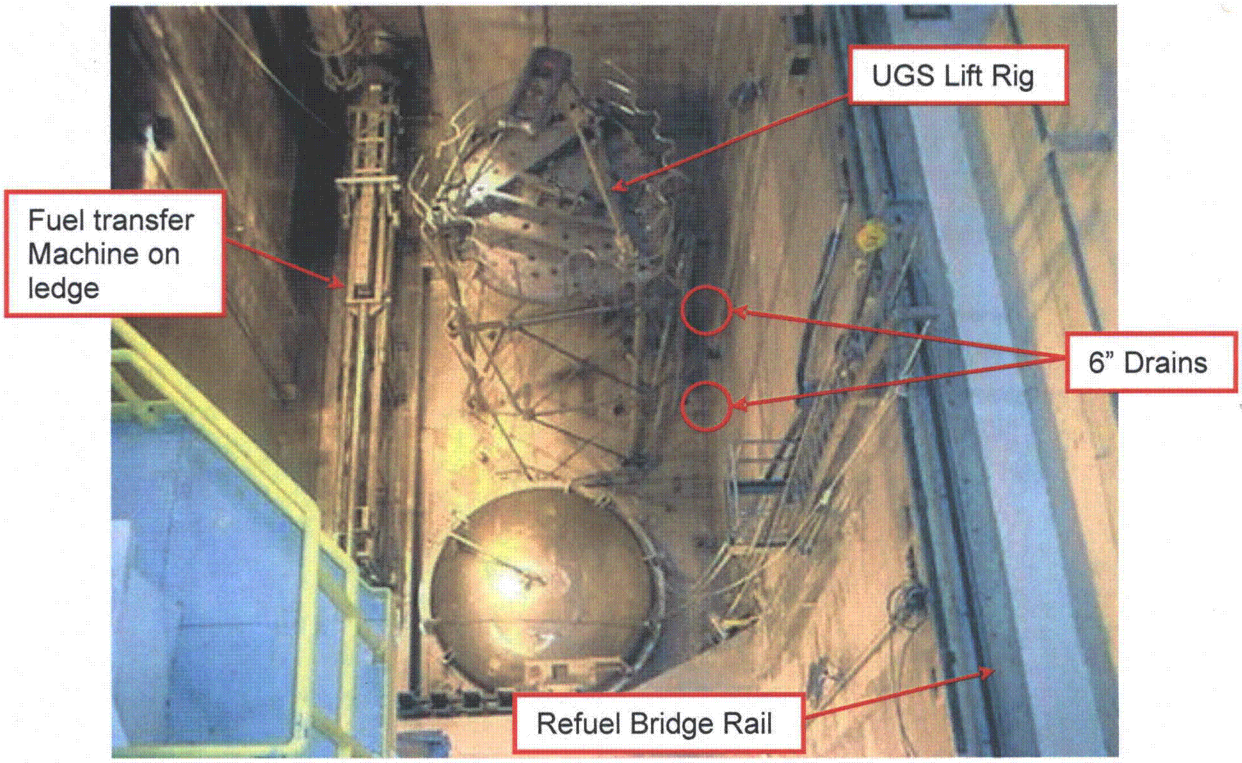


Figure 36-2: Reactor Cavity Obstructions - 1

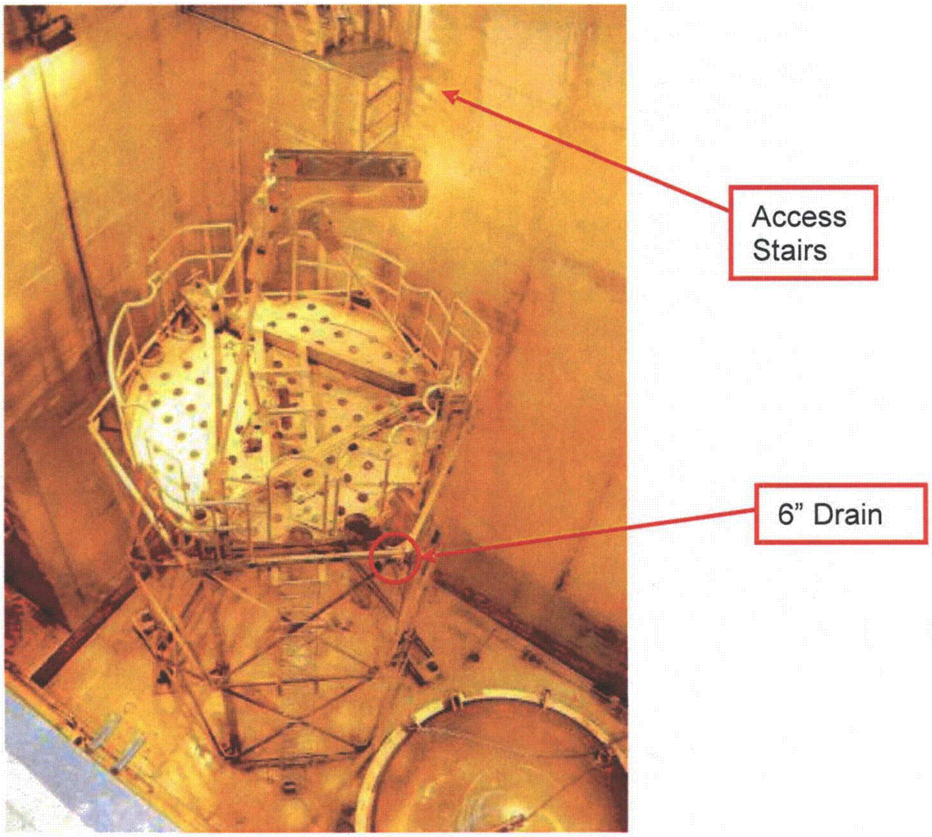
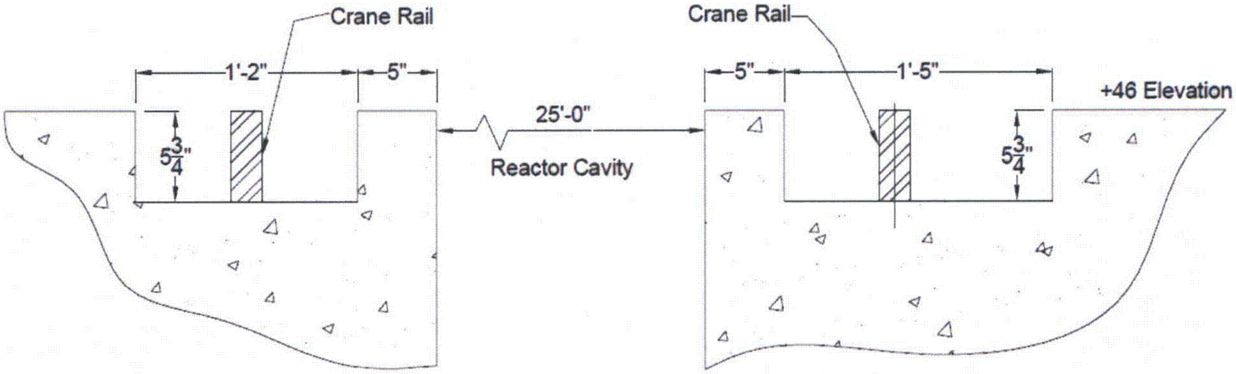


Figure 36-3: Reactor Cavity Obstructions - 2

The Refueling Bridge rails run along both sides of the refueling cavity at the +46 foot elevation. The rails lie in troughs that are 5.75 inches deep and a minimum of 14” wide. These troughs and rails will prevent debris that could land on the +46 elevation from washing directly into the pool due to containment spray.



Elevation View
Refuel Machine Rail on West Side of
Reactor Cavity

Elevation View
Refuel Machine Rail on East Side of
Reactor Cavity

Figure 36-4: Refuel Machine Rails

With the obstructions shown to be in the D-rings that will help prevent large debris from flying up into the upper reaches of containment, the items that are blocking debris from falling directly down onto the drains inside the cavity, and the refueling bridge rails stopping large debris from flowing over the sides of the canal walls and down into the cavity, Waterford 3 has shown that large debris will not cover the drains and block containment spray flow from leaving the cavity.

F. Coatings Evaluation

<u>*NRC RAI 37:*</u>
In the submittal response dated October 23,2008, a 4D ZOI was used for inorganic zinc coatings. TR WCAP-16568-P, Revision 1, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings" (ADAMS Accession No. ML061990594, Not Publicly Available), recommends using a 5D ZOI for untopcoated inorganic zinc. Please confirm that the inorganic zinc is topcoated or provide justification for using a 4D ZOI for untopcoated inorganic zinc coatings.

<u>WF3 Response 37:</u>
All inorganic zinc (IOZ) within a 10D ZOI of any of the breaks has an epoxy topcoat. The coating specifications for Waterford 3 do not show any Service Level 1 (DBA Qualified) IOZ being used for structural steel or containment vessel without an epoxy coating. Therefore, Waterford 3 will use the 4D ZOI for epoxy coatings as documented in Topical Report WCAP-16568-P.

G. Downstream Effects/In-vessel

<u>*NRC RAI 38:*</u>
The NRC staff does not consider in-vessel downstream effects to be fully addressed at Waterford 3, as well as at other PWRs. Waterford 3'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 Waterford 3 by showing that the licensee's plant conditions are bounded by the final WCAP-16793-NP and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating without reference to WCAP-16793 or the NRC staff SE that in-vessel downstream effects have been addressed at Waterford 3. Please report how the in-vessel downstream effects issue has been addressed for Waterford 3 within 90 days of issuance of the final NRC staff SE on WCAP-16793.

<u>WF3 Response 38:</u>
In-vessel downstream effects issue will be addressed after issuance of the final NRC staff SE on WCAP-16793.

Commitment 3: Address in-vessel downstream effects after issuance of the NRC Safety Evaluation for WCAP-16793.

J. Chemical Effects

NRC RAI 39:
The supplemental responses provided insufficient information for the NRC staff to conclude that chemical effects have been satisfactorily addressed at Waterford. Please provide the results from chemical effects tests considering the "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant-Specific Chemical Effect Evaluations," dated March 28, 2008 (ADAMS Accession No. ML080380214).

NRC RAI 40:
The supplemental response dated October 23, 2008, states that 30-day integrated chemical effects testing performed by Alion Science and Technology will be used to determine to head loss contribution due to chemical precipitates. Please describe the methodology for applying the integrated chemical effects testing results to the hydraulic head loss test results.

NRC RAI 41:
The NRC staff has had extensive interaction with Alion regarding the integrated chemical effects testing in the VUEZ loops. During these interactions, several technical concerns have been raised. For example, the staff questioned whether a poured debris bed provided a representative baseline head loss from which to calculate a bump up factor. For a complete list of issues, please see "NRC Staff Questions with Problem Statements," (Enclosure 6 to a phone call summary of the October 31,2007 and November 29,2007 phone calls with Alion, ADAMS Accession No. ML08051 0657). Please describe the test protocol for the VUEZ testing conducted for Waterford 3 and address the outstanding staff concerns with the Alion VUEZ test protocol as applicable to the Waterford 3 testing.

NRC RAI 42:
Please clarify or justify the statement: "The 30 day integrated testing and analyses concluded that no aluminum-based precipitates would form in the Waterford 3 environmental conditions with a pH less than 8.1." Lower pH would tend to favor precipitation since the aluminum solubility would decrease as the pH decreased below a pH of 8.1.

NRC RAI 43:
Please provide the expected Waterford 3 equilibrium pH range, the projected Waterford 3 aluminum concentration, and the post-LOCA temperature profile used to reach the conclusion that aluminum-based precipitates would not form.

NRC RAI 44:
Please explain what test parameters were measured to determine that no aluminum-based precipitates were formed above 140 °F, and explain whether it is possible that precipitates formed at temperatures above 140 °F but were not detected during the test.

WF3 Response 39 – 44:
To address recent changes to post-accident debris source terms and the resulting strainer debris loads and containment sump chemistry, Waterford 3 conducted new head loss tests in June – July 2010 with revised non-chemical debris loads and WCAP-16530 type surrogates.

The results of the 2010 test program supersede the existing test data that was referenced in the supplemental response, and the results of VUEZ integrated tests are no longer used for Waterford 3 strainer qualification. Application of WCAP-16530 was consistent with NRC SER recommendations and is discussed below.

The evaluation of chemical effects involved a two step process. The first step was to determine the plant specific chemical precipitate loading utilizing the WCAP-16530 model. The second step was to perform plant specific head loss testing utilizing the WCAP-16530 precipitate loading.

Waterford 3 chemical effects precipitate loading was analyzed by Alion Science & Technology utilizing the guidance provided in WCAP-16530 and version 1.1 of the associated spreadsheet tool. No refinements or exceptions were made to the base model. Plant specific inputs were used in a conservative manner to maximize precipitate loading. The following three notable conservatisms are applied to the analysis.

- The sump is assumed to not be mixed throughout the model. The difference in precipitate generation between assuming a mixed pool and non-mixed pool is small; however, assuming a non-mixed pool conservatively maximizes the amount of material dissolved and thus maximizes the amounts of precipitates generated.

- Per WCAP-16530 Section 6.4, it was assumed that all dissolved aluminum will form precipitates.

- To account for NRC observations and recommendations in the SER of WCAP-16530 regarding the use of a time-based aluminum dissolution analysis, the release rate of aluminum is doubled in the analysis for the first 15 days for both submerged and unsubmerged metallic aluminum to bound the ICET 1 test data.

Table 39-1 lists the Waterford 3 specific input utilized in the analysis for the design case. Based on the results of the WCAP-16530 analysis of the Waterford 3 debris load and post-LOCA containment sump chemistry, aluminum is the limiting reactant in the formation of sodium aluminum silicate, and no aluminum oxyhydroxide is formed. The corrosion/dissolution sources contributing to elemental release quantities and precipitates for the limiting case (Maximum volume, Maximum pH) are included as Figure 39-2 and Figure 39-3. Nukon and MEI, which are composed of E-Glass, are the primary sources of calcium and silicon. The TSP buffer reacts with the dissolved calcium released from E-glass, as well as from concrete, to form calcium phosphate precipitate. Unsubmerged aluminum is the primary source of dissolved aluminum, followed by E-glass and submerged aluminum.

Parameter	Value
Time of Recirculation Actuation	3253.19 sec
Time at which spray is terminated	30 days

Max. Recirculation Water Volume	102,810 ft³
Min. Recirculation water Volume	42,938 ft³
Buffering Agent	TSP
Temperature	See Figure 39-1
Boric Acid Concentration of RWSP	2050 – 2900 ppm
Maximum Sump pH	8.1
Minimum Sump pH	7.1 (1h – 10d); 7.0 (20d – 30d)
Metallic Aluminum	Submerged 10 ft² / 10 lb Unsubmerged 140 ft² / 340 lb
Fiberglass Insulation (MEI/Nukon/Latent)	808.1 ft³
Silica Powder (Min-K/Microtherm)	4.6 ft³
Concrete (exposed & submerged total)	81,558 ft²
Aluminum Silicate	None
Calcium Silicate	None

Table 39-1: Plant Specific Inputs (Design)

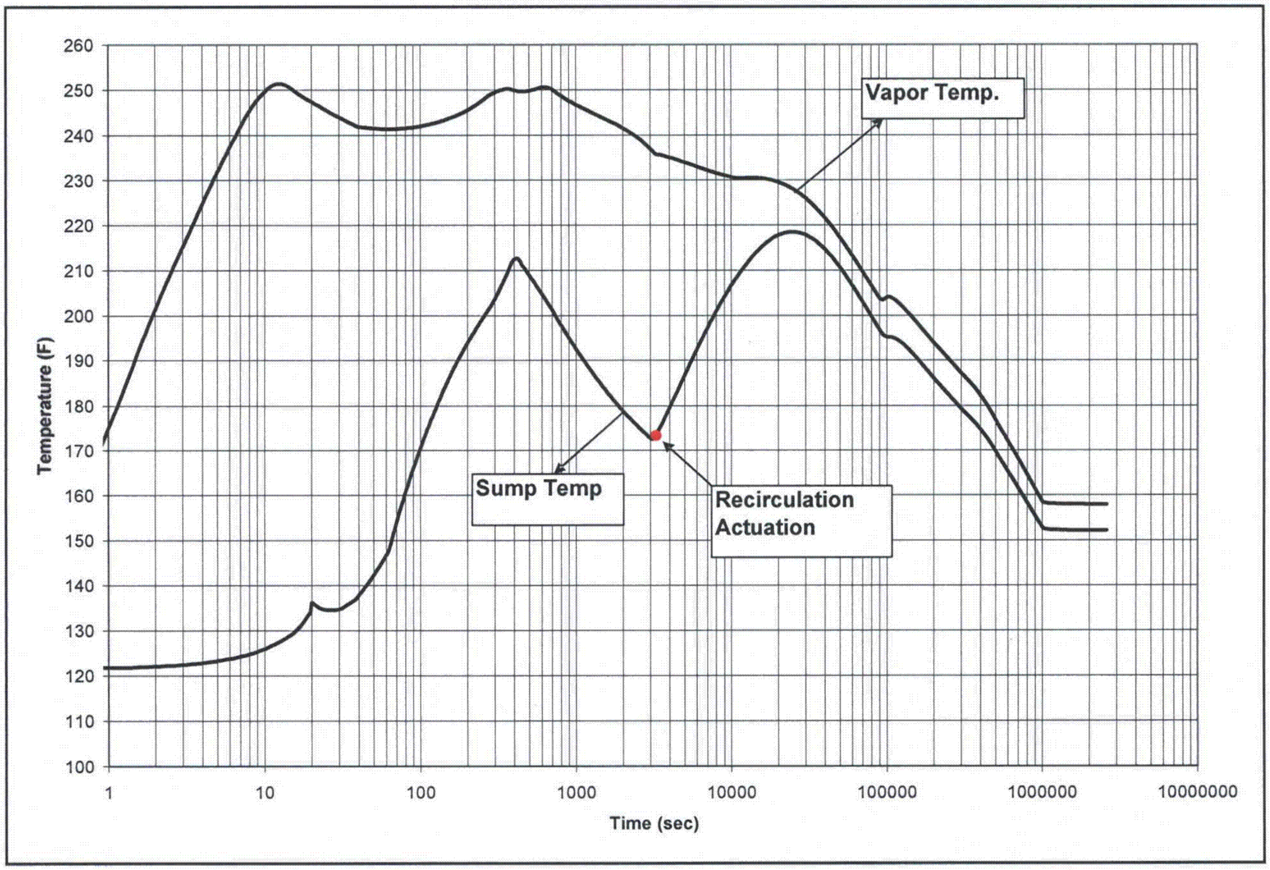
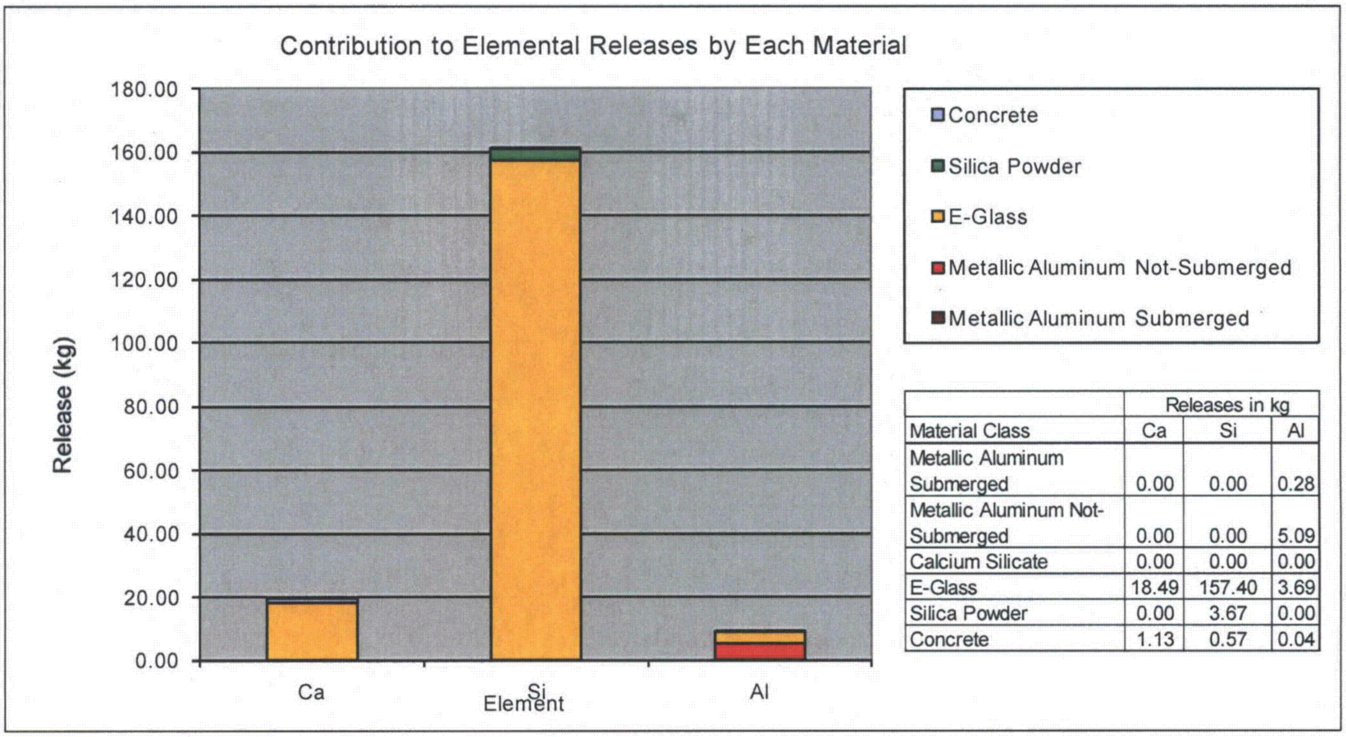
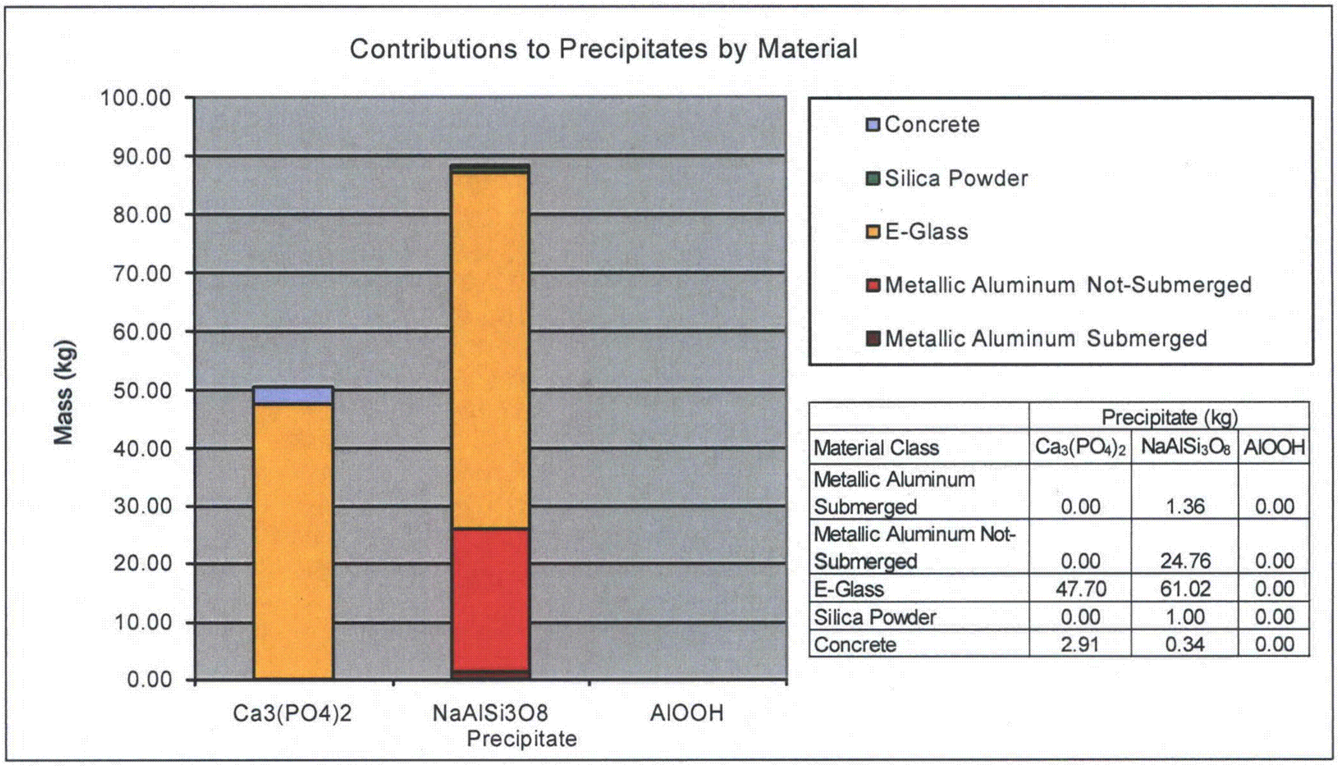


Figure 39-1: Maximum Temperature Profile Used in Chemical Effects Analysis



	Releases in kg		
Material Class	Ca	Si	Al
Metallic Aluminum Submerged	0.00	0.00	0.28
Metallic Aluminum Not-Submerged	0.00	0.00	5.09
Calcium Silicate	0.00	0.00	0.00
E-Glass	18.49	157.40	3.69
Silica Powder	0.00	3.67	0.00
Concrete	1.13	0.57	0.04

Figure 39-2: Elemental Release by Material (Design)



	Precipitate (kg)		
Material Class	$Ca_3(PO_4)_2$	$NaAlSi_3O_8$	AlOOH
Metallic Aluminum Submerged	0.00	1.36	0.00
Metallic Aluminum Not-Submerged	0.00	24.76	0.00
E-Glass	47.70	61.02	0.00
Silica Powder	0.00	1.00	0.00
Concrete	2.91	0.34	0.00

Figure 39-3: Precipitate by Material (Design)

Three chemical effects head loss tests were conducted utilizing the predicted chemical loadings. For all three tests, a fiber and particulate debris bed was formed on a representative plant strainer module section and a stabilized head loss was determined. Calcium Phosphate (CaP) was then added in three batches with stabilized head loss values determined after each batch. Sodium Aluminum Silicate (NAS) was then added in three batches with stabilized head loss values determined after each batch. No Aluminum Oxyhydroxide is predicted to form in the Waterford 3 post-LOCA sump and therefore was not used in testing.

The first test, Full Load, utilized design basis loadings for fiber, particulate and chemicals. The second test, Thin Bed, used the same loading as the first test and focused on evaluating thin bed effects. The third test, Additional Margin, increased fiber loading to 10% above design (particulate loading did not change and chemicals were adjusted to match fiber). Raw results (not scaled or extrapolated for mission time) for all three tests are shown in Tables 39-2 through 39-4 below.

Test Point	Head Loss (ft)	Ave. Theoretical Approach Velocity (ft/s)	Flow (gpm)
Clean Screen	0.054	0.00475	230
Particulate	0.056	0.00477	231
Fiber Batch 1	0.073	0.00479	232
Fiber Batch 2	0.087	0.00477	231
Fiber Batch 3	0.112	0.00477	231
Fiber Batch 4	0.152	0.00470	228
Fiber Batch 5	0.185	0.00469	228
Fiber Batch 6	0.257	0.00469	228
Fiber Batch 7	0.352	0.00469	228
CP Batch 1	0.601	0.00466	226
CP Batch 2	0.688	0.00466	226
CP Batch 3	0.960	0.00456	221
NAS Batch 1	1.478	0.00463	224
NAS Batch2	1.708	0.00455	221
NAS Batch 3	2.322	0.00467	226

Table 39-2: Thin Bed Test Raw Data Points (WF3-TB)

Test Point	Head Loss (ft)	Ave. Theoretical Approach Velocity (ft/s)	Flow (gpm)
Clean Screen	0.045	0.00465	226
Fiber/Particulate Batch 1	0.056	0.00475	231
Fiber/Particulate Batch 2	0.077	0.00478	232
Fiber/Particulate Batch 3	0.159	0.00476	231
Fiber/Particulate Batch 4	0.508	0.00469	228
CP Batch 1	0.542	0.00467	227
CP Batch 2	0.770	0.00465	225
CP Batch 3	1.180	0.00459	223

NAS Batch 1	1.685	0.00469	228
NAS Batch2	1.759	0.00466	226
NAS Batch 3	1.824	0.00467	226

Table 39-3: Full Load Test Raw Data Points (WF3-FL)

Test Point	Head Loss (ft)	Ave. Theoretical Approach Velocity (ft/s)	Flow (gpm)
Clean Screen	0.042	0.00467	226
Fiber/Particulate Batch 1	0.037	0.00467	226
Fiber/Particulate Batch 2	0.071	0.00465	225
Fiber/Particulate Batch 3	0.193	0.00469	227
Fiber/Particulate Batch 4	0.566	0.00473	229
CP Batch 1	1.121	0.00460	222
CP Batch 2	1.224	0.00465	225
CP Batch 3	1.793	0.00467	226
NAS Batch 1	1.980	0.00471	228
NAS Batch2	1.997	0.00469	227
NAS Batch 3	2.925	0.00451	218

Table 39-3: Additional Margin Test Raw Data Points (WF3-AM)

After raw data smoothing, extrapolation, and scaling, the case with CaP and NAS, WF3-TB resulted in the highest head loss in the short-term, while both WF3-TB and WF3-FL resulted in the same long-term head loss. For the case with CaP only (elevated sump temperature) WF3-FL resulted in the highest short-term head loss and highest long-term head loss. Table 39-4 includes the Waterford 3 ECCS strainer design basis head loss for each temperature and time. The head loss at a range of times and temperatures for the additional margin case, WF3-AM, is included in Table 39-5.

Temperature (°F)	Time (hr)	Debris Head Loss (ft)	Clean Head Loss (ft)	Total Strainer Head Loss (ft)
210	7.3	0.84 (1.67)	0.23	1.07 (1.90)
	720	1.25 (2.03)		1.48 (2.26)
90	23.7	2.29	0.29	2.58
	720	2.75		3.04

Table 39-4: ECCS Strainer post-LOCA Head Loss (Design Basis Debris Loads)
Note: Value in parentheses indicate predicted plant debris head loss and total strainer head loss without credit for aluminum solubility.

Temperature (°F)	Time (hr)	Debris Head Loss (ft)	Clean Head Loss (ft)	Total Strainer Head Loss (ft)
210	15.4	1.46 (2.44)	0.23	1.69 (2.67)
	720	1.86 (3.04)		2.09 (3.27)
90	40	2.95	0.29	3.24
	720	3.66		3.95

Table 39-5: ECCS Strainer post-LOCA Head Loss (Additional Margin Case)
Note: Value in parentheses indicate predicted plant debris head loss and total strainer head loss without credit for aluminum solubility.

The times included in Table 39-4 and Table 39-5 indicate the times for each test to stabilize at the maximum head loss value that was used to determine the corresponding plant head loss in the table. The time column lists the maximum plant durations to which the provided head loss values can be applied.

Utilizing the Argonne National Laboratory (ANL) correlation, credit for aluminum solubility is taken only at sump temperatures above 146°F. The predicted WCAP-16530 released aluminum concentration is compared to the aluminum solubility predicted using the ANL correlation in Figure 39-4 and Figure 39-5, which clearly indicate that the aluminum solubility limit far exceeds the dissolved aluminum concentration for the entire accident duration for the both the minimum and maximum pH cases. A second aluminum solubility curve calculated at 20°F below the aluminum release rate temperature is included as well to show margin. Since the aluminum solubility limit increases with temperature, it is conservative to use a reduced temperature for solubility calculations. Figure 39-6 shows the aluminum solubility and concentration for the margin case, which includes the additional margin fiber loading. This case is based on the limiting minimum water, minimum pH case. Figure 39-6 is consistent with the previous figures in showing that the concentration is exceeded by the solubility.

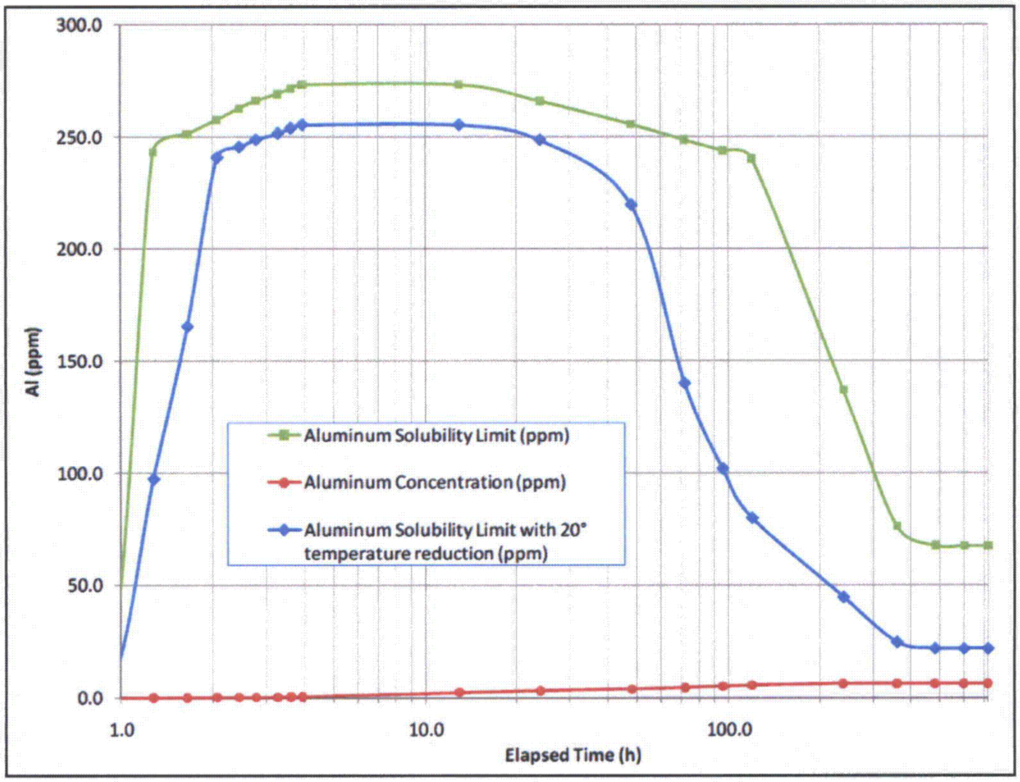


Figure 39-4: WCAP-16530 Time Based Analysis and Aluminum Solubility – Max pH

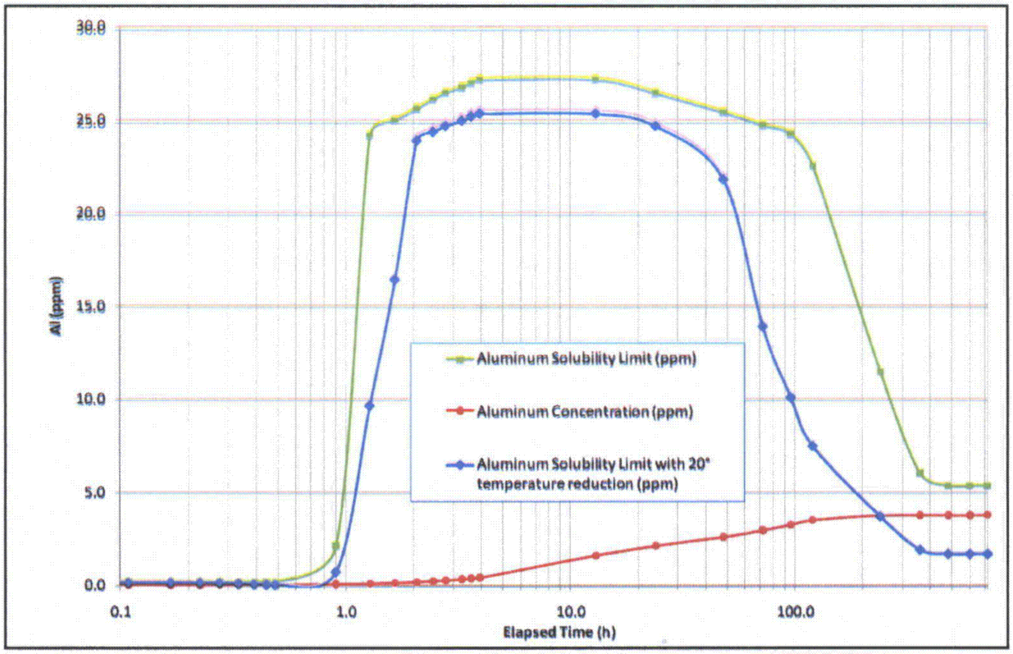


Figure 39-5: WCAP-16530 Time Based Analysis and Aluminum Solubility – Min pH

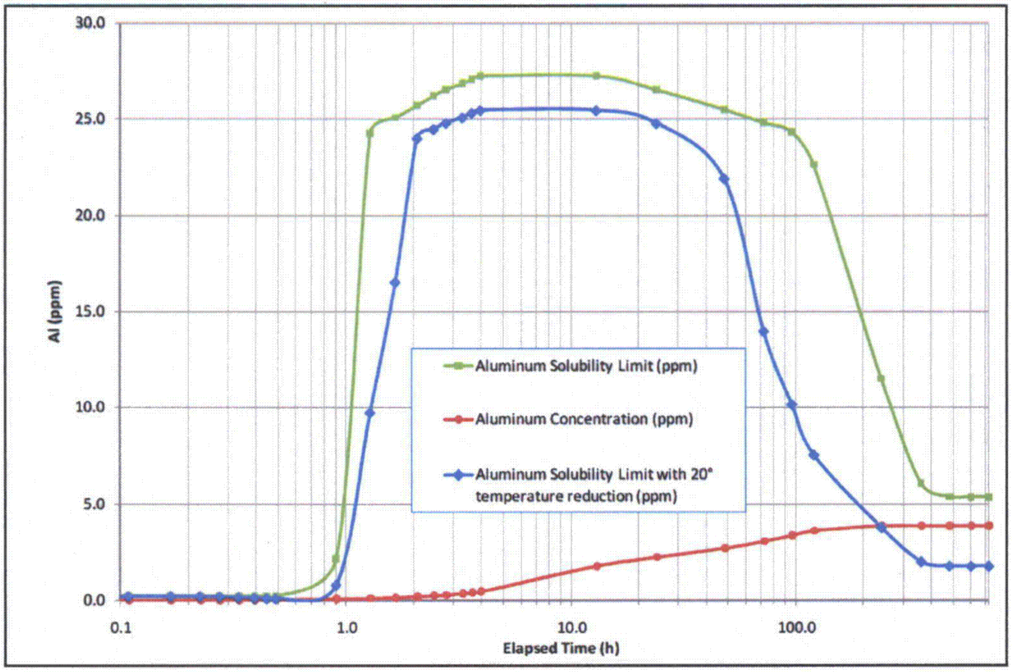


Figure 39-6: WCAP-16530 Time Based Analysis and Aluminum Solubility – Min pH with Margin Fiber added

WCAP-16530 results are compared to aluminum solubility vs. temperature profiles in Figure 39-7 and Figure 39-8. The comparison is conducted at the minimum pH and minimum water volume to minimize aluminum solubility while maximizing aluminum concentration at the minimum pH. This reduces the amount of aluminum released as compared to the maximum pH case, but the aluminum solubility limit is lowered substantially, making the minimum pH case the limiting case with regard to aluminum solubility. The aluminum solubility limit is higher than the maximum aluminum concentration until the temperature falls to 145°F, meaning that no aluminum will precipitate at temperatures above 145°F at the sump pH and maximum aluminum concentration. Based on the minimum pH condition in Figure 39-7, the solubility limit of aluminum falls below the concentration of dissolved aluminum at a temperature of 145°F and at 3.74 ppm aluminum. With the extra margin added in Figure 39-8, the solubility limit of aluminum falls below the concentration of dissolved aluminum at approximately 146°F and at 3.82 ppm aluminum.

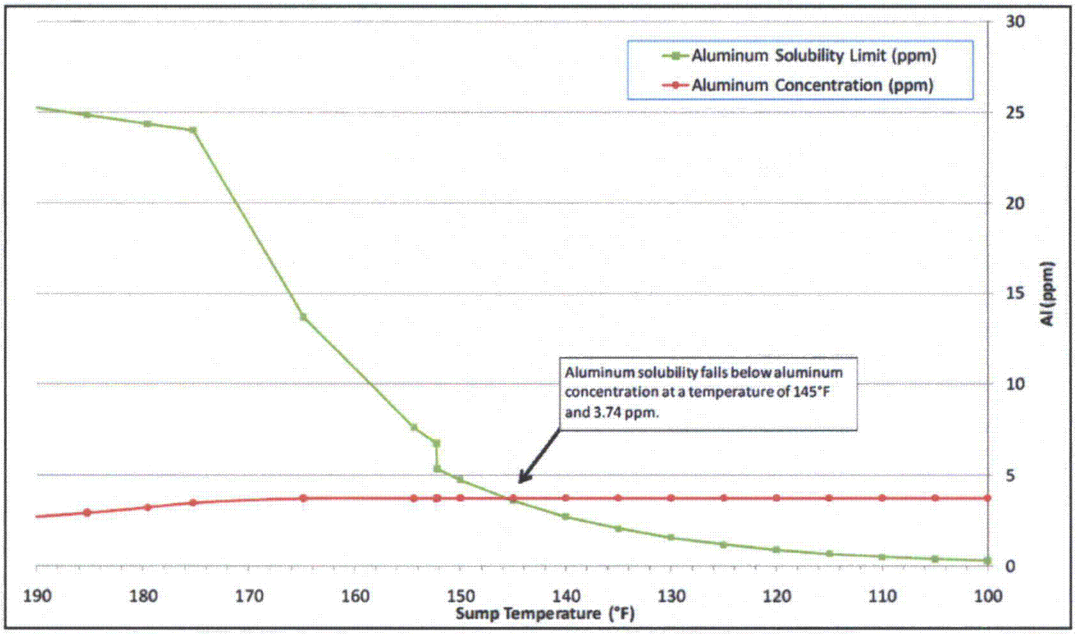


Figure 39-7: WCAP-16530 Time Based Analysis and Aluminum Solubility

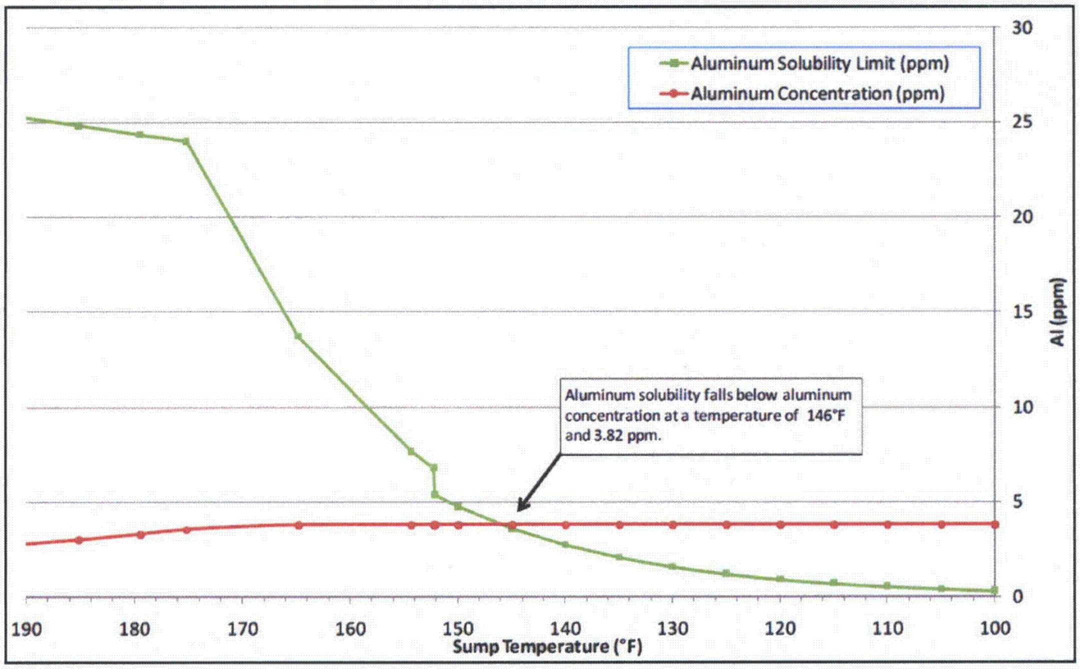


Figure 39-8: WCAP-16530 Time Based Analysis and Aluminum Solubility with Margin

A limitation to the application of the aluminum solubility correlations is that the data used to derive them was acquired in an essentially silicon-free environment, which precluded the formation of sodium aluminum silicate as predicted by WCAP-16530. However, although WCAP-16530 predicts the formation of sodium aluminum silicate in high-silicon conditions when any aluminum is present, small amounts of sodium aluminum silicate (~4 ppm Al-equivalent) have been shown to have no effect on debris head loss at temperatures above 140°F in vertical loop head loss tests (ALION-CAL-SNC-7487-003, "Vogtle High Temperature Vertical Loop Test Report"). The test results contained in ALION-CAL-SNC-7487-003 were obtained using a TSP buffered solution with 4.2 ppm aluminum and 26 ppm silicon, with a pH of 7.6. Based on these results, the ANL solubility correlation can be conservatively applied to the Waterford 3 conditions to predict aluminum solubility. For additional conservatism, the solubility credit is only applied in the NPSH analyses at temperatures above 200 °F.

Attachment 2

W3F1-2010-0032

List of Regulatory Commitments

List of Regulatory Commitments

The following table identifies those actions committed to by Entergy in this document. Any other statements in this submittal are provided for information purposes and are not considered to be regulatory commitments.

COMMITMENT	TYPE (Check One)		SCHEDULED COMPLETION DATE (If Required)
	ONE-TIME ACTION	CONTINUING COMPLIANCE	
Commitment 1: Waterford 3 will replace the fibrous insulation on the current steam generators with Reflective Metal Insulation.	x		Prior to Mode 4 after Refueling Outage 17
Commitment 2: Revise Emergency Operating Procedures to include contingency actions for a Low Pressure Safety Injection pump failing to trip on Recirculation Actuation Signal.		x	Prior to Mode 4 after Refueling Outage 17
Commitment 3: Address in-vessel downstream effects after issuance of the NRC Safety Evaluation for WCAP-16793.	x		Within 90 days of issuance of NRC Safety Evaluation for WCAP-16793