NextEra Energy
POINT BEACH

July 31, 2009

NRC 2009-0077
GL 2004-02

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

Point Beach Nuclear Plant, Units 1 and 2
Dockets 50-266 and 50-301
Renewed License Nos. DPR-24 and DPR-27

Response to Request for Additional Information
GSI-191/GL 2004-02 (TAC NOS. MC4705/4706)
Potential Impact of Debris Blockage on Emergency Recirculation
During Design Basis Accidents at Pressurized Water Reactors

References:

(1) FPL Energy Point Beach, LLC, Letter to NRC dated February 29, 2008, Supplemental Response to GL 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (ML080630613)

(2) FPL Energy Point Beach, LLC, Letter to NRC dated June 9, 2008, Supplemental Response to GL 2004-02, Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (ML081620337)

(3) NRC Letter to FPL Energy Point Beach Nuclear Plant Units 1 and 2 GSI-191/GL 2004-02, Request for Additional Information (TAC NOS. MC4705/4706), dated January 7, 2009 (ML083300173)

(4) FPL Energy Point Beach, LLC, Letter to NRC dated April 7, 2009, Response to Request for Additional Information, GSI-191/GL 2004-02 (TAC NOS. MC4705/4706) Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors (ML 090980523)

NextEra Energy Point Beach, LLC (NextEra), (formerly FPL Energy Point Beach, LLC), previously submitted supplemental responses to Generic Letter (GL) 2004-02 in References (1) and (2). Reference (3) contains a request for additional information (RAI) based upon NRC Staff reviews of References (1) and (2).

Enclosure 1 contains the NextEra response to the RAI questions pending final debris generation and transport analyses results. To enable NRC staff review, the responses include those previously provided by Reference (4). Information that has been changed or appended since submittal of Reference (4) is indicated by a vertical bar in the left hand margin. Enclosures 2 through 6 are provided in support of information summarized in Enclosure 1.

This letter contains no new Regulatory Commitments and no revisions to existing Regulatory Commitments.

If you have questions or require additional information, please contact Mr. James Costedio at 920/755-7427.

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

Executed on July 31, 2009.

Very truly yours,

NextEra Energy Point Beach, LLC

Larry Meyer
Site Vice President

Enclosures

cc: Administrator, Region III, USNRC
Project Manager, Point Beach Nuclear Plant, USNRC
Resident Inspector, Point Beach Nuclear Plant, USNRC
PSCW

ENCLOSURE 1

NEXTERA ENERGY POINT BEACH, LLC
POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
GSI-191/GL 2004-02 (TAC NOS. MC4705/4706)
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

The following information is provided by NextEra Energy Point Beach, LLC (NextEra), in response to the NRC staff's request for additional information dated January 7, 2009.

Question 1

Please provide the insulation material(s) for the reactor vessel. Please state whether the debris quantities generated by breaks at reactor vessel nozzles that reach the strainer are bounded by the debris that transports from other breaks that have already been evaluated. If the debris quantities from previously breaks are not bounding, please evaluate the effects of the reactor vessel nozzle break on strainer head loss.

NextEra Response

The reactor vessels for both Point Beach Nuclear Plant (PBNP) units are insulated with reflective metal insulation (RMI). This includes the vessel circumferential insulation, the lower head and the upper reactor vessel head. The jacketing and the foils of the RMI are stainless steel.

The insulation on the piping connected to the vessel nozzles is RMI with the exception of an approximately 17" wide removable belt around each of the pipe-to-nozzle welds to facilitate inservice inspections. This belt of insulation is fibrous NUKON® in most locations and Temp-Mat® with a sewn envelope of asbestos bearing cloth in two locations. The removable belts of fibrous insulation have a volume of approximately 5 ft^3 each, for a total of approximately 20 ft^3 for the four nozzles on each reactor vessel.

Breaks originating at the reactor vessel nozzles have not been explicitly modeled to determine the amount of debris that would be generated. However, the quantity of fibrous and particulate debris is reasonably bounded by other modeled breaks.

The reactor vessels are enclosed within the steel reinforced concrete primary shield wall. Jets from a break originating at the vessel nozzles would be expected to emanate in a predominantly radial direction outward from the nozzle rather than axially along the pipe wall. Axial offsetting between the reactor coolant system (RCS) piping and the reactor vessel nozzles would be substantially limited by the reactor vessel supports and the reactor primary shield wall penetration housing each of the loop pipes. As such, direct jetting axially along the pipe through an RCS loop piping penetration in the primary shield wall is expected to be minimal.

Insulation debris stripped and ejected through penetrations in the primary shield wall by a loss of coolant accident (LOCA) at the reactor vessel nozzles would be mostly RMI debris. The majority of the RMI debris generated would be expected to remain within the primary shield wall, an inactive sump. The RMI debris that may be ejected would not be subject to significant transport by the low velocity flows in the active sump. As such, the debris generated is considered to be bounded by the relatively large quantities of fibrous and particulate debris that could be generated by a break of RCS piping within the RCS loop compartments so no further detailed evaluation of the effects has been performed.

Question 2

Please provide the information concerning the debris characteristics analysis that was requested in the U.S. Nuclear Regulatory Commission (NRC) staff revised content guide.

NextEra Response

Revised Content Guide for Generic Letter 2004-02 Supplemental Responses, November 2007, (ML073110278), identifies the following as required specific information regarding methodology for demonstrating compliance:

"Debris Characteristics

The objective of the debris characteristics determination process is to establish a conservative debris characteristics profile for use in determining the transportability of debris and its contribution to head loss.

- Provide the assumed size distribution for each type of debris.
- Provide bulk densities (i.e., including voids between the fibers/particles) and material densities (i.e., the density of the microscopic fibers/particles themselves) for fibrous and particulate debris.
- Provide assumed specific surface areas for fibrous and particulate debris.
- Provide the technical basis for any debris characterization assumptions that deviate from NRC-approved guidance."

During a December 22, 2008, telephone conference held between representatives of the NRC staff and FPL Energy Point Beach, it was acknowledged that much of the requested information pertaining to the characteristics of the debris would not be necessary, and that some information was not available, as a result of site efforts to qualify screen performance by testing rather than analysis. It was also acknowledged that pertinent details of the materials and surrogates used in the tests are needed, and in particular, details of how these materials and surrogates were prepared for the tests.

Debris was added to the flumes for the screen test by weight. The weights were calculated using the volumes from the debris generation and transport calculations, multiplied by conservatively assumed as-manufactured densities of various materials. The information in the table below was excerpted from the strainer design basis loading test plan. The plan lists the debris types as determined by the debris generation analysis, the assumed densities for these debris types, the corresponding surrogate materials used in the flume tests, and the method of preparation for the surrogates. The tabulated densities were previously approved in Nuclear Energy Institute, NEI-04-07, Pressurized Water Reactor Sump Performance Evaluation Methodology, dated May 28, 2004, (ML041550279, ML041550332, ML041550359 and ML041550380).

Materials Used for Screen Testing

Debris Type	Density (lb/ft^3)	Surrogate Test Material	Surrogate Processing
Asbestos fiber (90% fines)	10	Ceramic fiber	Shredder
NUKON® (large)	2.4	NUKON®	Chunks >1"x4"
NUKON® (small)	2.4	NUKON®	Wood chipper
NUKON® (fines)	2.4	Baked-out NUKON®	Shredder
Temp Mat® (large)	11.8	Temp Mat®	Chunks >1"x4"
Temp Mat® (small)	11.8	Temp Mat®	Wood chipper
Temp Mat® (fines)	11.8	Temp Mat®	Shredder
Fiberglass (small)	5.5	Owens Corning Fiberglass	Wood chipper
Fiberglass (fines)	5.5	Owens Corning Fiberglass	Shredder
Mineral Wool (small)	8.0	10 pcf MW Fiber	Wood chipper
Mineral Wool (fines)	8.0	10 pcf MW Fiber	Shredder
Latent fibers	N/A (direct weight from analysis)	Baked-out NUKON®	Shredder
Asbestos particulates (10%)	10.0	Cal-Sil	Powdered
Cal-Sil	14.5	Cal-Sil	Powdered
Latent dirt & dust	N/A (direct weight from analysis)	PCI PWR Dirt Mix	N/A
Zinc Coatings	457	Tin Powder	N/A
Aluminum coatings	94	Walnut shells	Powdered
Alkyd coatings	90	Walnut shells	Powdered
Unqualified Epoxy	94	Walnut shells	Powdered
Qualified Epoxy in ZOI	94	Walnut shells	Powdered
Degraded Epoxy (chips)	94	Acrylic	1/64" - ¼" chips

For further details about the preparation of the surrogate materials, their size distributions (fines, smalls, larges and intact), and the technical basis for the use of the various surrogates, refer to Performance Contracting Inc. Letter to NRC, dated March 25, 2009, PCI-6016-02.01, Attachment 3, Sure-Flow® Suction Strainer – Testing Debris Preparation and Surrogates, SFSS-TD-2007, Revision 4 (Proprietary) (ML090900476).

All of the asbestos fiber (assumed to be 90% of the insulation mass) was assumed to be fine fibers and was processed as such for the screen test. The intent was to allocate 50% of the asbestos fiber as fines and 50% as smalls. The error in allocating these as fines was conservative. Fractions are conservative from two aspects; the high percentage of assumed fiber content, and the assumption that a major fraction of all of that fiber is reduced to a fine and transportable form. It is expected that a substantial portion of the asbestos insulation would remain in lumps or intact pieces and not be reduced to individual fibers of fine dimensions. Destructive testing was not performed.

During a June 22, 2009, telephone conference held between representatives of the NRC staff and NextEra, additional information was requested detailing the size distributions for each debris type and specifying whether zones of influence (ZOIs) are to be reduced from the approved guidance in NEI 04-07, Volume II. The following information is provided based on previously performed debris analyses. No changes in approach or methodology are expected for the analyses to be performed in the future.

Debris sizing for the blast, blowdown and pool fill phases of the accident conforms to the approved guidance of NEI 04-07, Section 3.4.3.3. Two groupings are used ("large" and "small"). Forty-percent of the NUKON® and Temp-Mat® were assumed to be "large" debris, with the balance, (60%), being reduced to "small" debris.

RMI debris was assumed to be 25% large pieces with 75% reduced to "small fines".

Calcium silicate (Cal-Sil) insulation was conservatively assumed to be 100% reduced to particulates to bound erosion effects that may occur.

Other fibrous debris types (e.g., mineral wool, generic fiberglass, etc), were to be 100% reduced to "small fines".

NextEra is supporting industry efforts to demonstrate by testing and/or analysis that jacketed NUKON® will remain intact at substantially less than the 17D ZOI endorsed in NEI 04-07. Previous efforts at PBNP have credited a reduced ZOI radius of 5 pipe diameters for jacketed NUKON® insulation. Current efforts will eliminate NUKON® to the extent necessary to ensure that it does not remain within the ZOI of large diameter, limiting pipe breaks. In particular, NUKON® is being removed from RCS piping, and from steam generator channel heads to ensure that there is no remaining NUKON® within a 5D radius of potential large bore break locations. Contingencies are in place to remove additional NUKON® to the extent necessary, including extended removal from the Unit 1 pressurizer and steam generator vertical sections, to preclude NUKON® involvement in design basis limiting ZOIs.

Question 3

Please provide the information concerning the debris transport analysis that was requested in the NRC staff revised content guide.

NextEra Response

The NRC staff revised content guide requests the following information:

"e. Debris Transport

The objective of the debris transport evaluation process is to estimate the fraction of debris that would be transported from debris sources within containment to the sump suction strainers.

- *Describe the methodology used to analyze debris transport during the blowdown, washdown, pool-fill-up, and recirculation phases of an accident.*
- *Provide the technical basis for assumptions and methods used in the analysis that deviate from the approved guidance.*
- *Identify any computational fluid dynamics codes used to compute debris transport fractions during recirculation and summarize the methodology, modeling assumptions, and results.*
- *Provide a summary of, and supporting basis for, any credit taken for debris interceptors.*
- *State whether fine debris was assumed to settle and provide basis for any settling credited.*
- *Provide the calculated debris transport fractions and the total quantities of each type of debris transported to the strainers."*

The following response reflects the methodology used in previously completed debris transport analyses. The previous analyses are being re-performed to reflect the planned elimination of fibrous insulation. It is expected that the pending analyses will use the same approach as the previous analyses without exception.

Due to variations in sump geometry, insulation types, and piping layouts, separate analyses have been performed for each unit. The analysis for each unit consists of two parts:

1. A distribution of debris due to the initial blowdown and subsequent pool fill, and

2. The transportation of debris toward the strainers due to containment washdown and containment sump recirculation.

These two parts are discussed separately below.

Blowdown / Pool-Fill

The approach used derives from the approved guidance of NEI 04-07. However, the approved guidance lacks several important details and necessary assumptions. Therefore, a description of the entire process is provided below.

Debris transports due to several factors, one of the most significant being the size of the debris. Two size groupings (small and large) are used in the analysis, consistent with NEI 04-07:

Debris Sizing Fractions Used In Blowdown / Pool Fill Analysis

Insulation Type	Small Fines	Large
RMI	75%	25%
Asbestos	100%	0%
CalSil	100%	0%
Fiberglass	100%	0%
Temp-Mat®/ Insulbatte	60%	40%
Mineral Wool	100%	0%
NUKON®	60%	40%

Small Debris

The small debris (defined as ≤ 4" along its longest dimension) is expected to become suspended in the air, moving upward through openings in robust barriers surrounding the break location, as well as downward. The pressure wave will likely carry the small debris a substantial distance from the break.

Although small debris originating in the RCS loop compartments will be widely distributed throughout containment, some of the distribution will be impeded by physical constraints within the loop compartment. Examples of such impediments include the compartment walls, the steam generators and reactor coolant pumps and the piping. In addition, the compartments contain numerous bar grate work platforms. These grates overlay the RCS components and will tend to impede small debris that is blasted up toward the refueling floor elevation. To account for these impediments, 50% of the total small debris generated is assumed to remain in the loop compartment at the end of the blast and pool fill phases. The remainder is assumed to leave the RCS loop compartment and be distributed throughout the containment building according to the sizes of the available openings.

While 50% of the "smalls" are assumed to be held up on interior structures, the testing that was performed (and is more fully described in response to Question 4) introduced a quantity of fines into the test flume that was based on a fraction of the full inventory of all fibrous debris generated within the containment. No reduction in testing fines was made as a result of the "small" debris assumed to be held up outside of the sump pool.

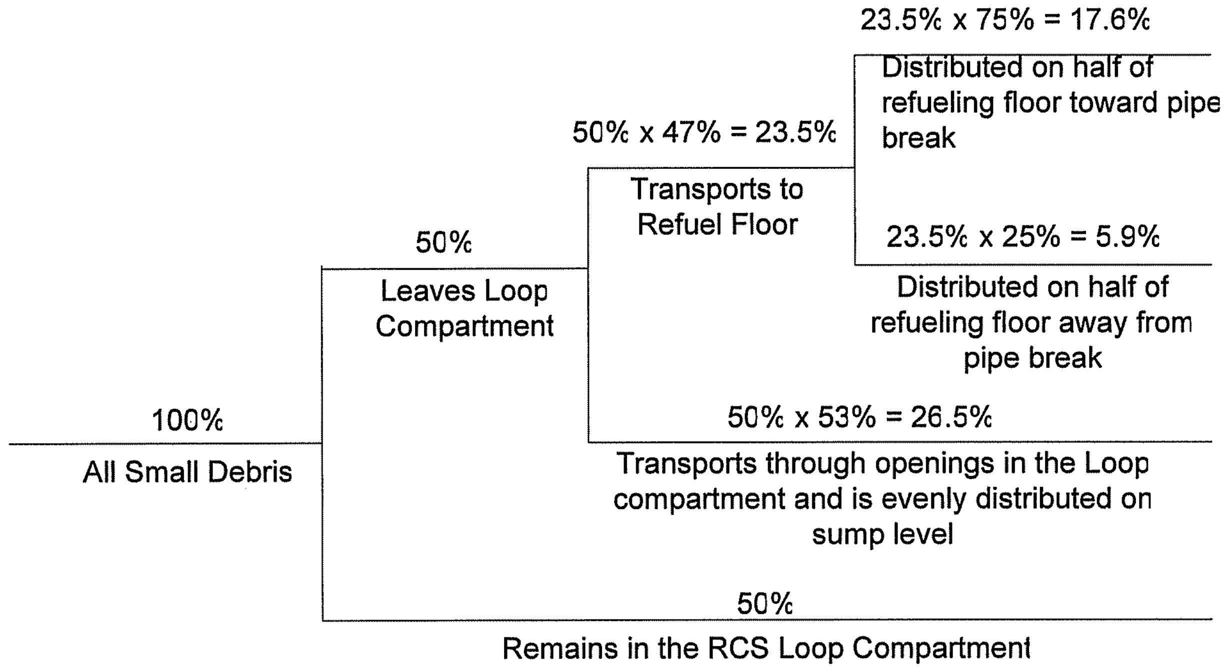
To determine the distribution of the small debris leaving the RCS loop compartments, the areas of the openings out of the compartments were calculated. For example, in Unit 2 on the Loop A side of containment there are seven openings. Five of the openings extend outward from the bottom of the RCS loop compartment into the sump level of the containment. The other two openings pass through the steam generator vault and reactor coolant pump cubicle. These openings provide a path through which the debris may reach the refueling floor. The following table illustrates the contribution of these openings to the fractional distribution of debris leaving the loop compartment:

Distribution of Small Debris Leaving an RCS Loop Compartment

Opening Designation	Passing To Zone #	Area (ft^2)	Percent of total opening area
A	111 (Sump elev.)	44.9	6.9%
B	108 (Sump elev.)	81.1	12.5%
C	108 (Sump elev.)	56.0	8.7%
D	109 (Sump elev.)	56.0	8.7%
E	110 (Sump elev.)	104.4	16.1%
RCP Cubicle	Refueling Floor	50.0	7.7%
SG Vault	Refueling Floor	254.2	39.3%
Total Open Area		646.6 ft^2	

The small debris transported to the refueling floor is distributed with preference toward the side of containment closest to the pipe break. The refueling floor surface area is divided into halves by a line running through the approximate center of the containment separating the two loop compartments. For breaks originating in a loop compartment, three-quarters of the debris is assumed to remain on the half of the refueling floor closest to the break, while one-quarter is assumed to be transported and evenly distributed on the remaining half of the refueling floor.

Once small debris is distributed to the various zones as described above, it is assumed to be evenly distributed throughout the zone by the combination of blowdown and pool fill. The resulting distribution logic tree for this example follows.



Example Distribution Logic of Small-Sized Debris that Originate in RCS Loop Compartment; Distribution due to Blow Down and Pool Fill Transport

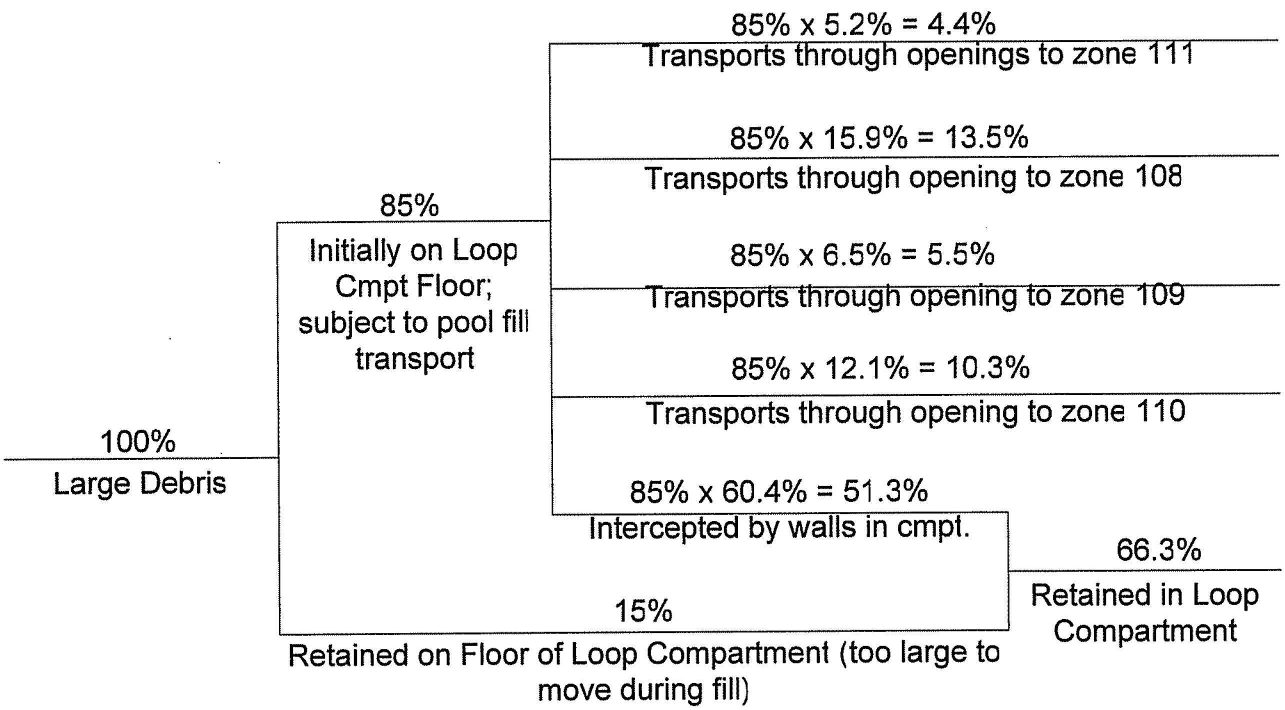
Large Debris

The large debris (defined as > 4" along its shortest dimension) is expected to be largely influenced by gravity and falls to the containment floor. Fifteen-percent of this debris is assumed to be large enough to remain on the floor below the break and not be transportable by blast or pool fill effects. Eighty-five percent of the debris is assumed to be subject to pool fill transport and will be pushed toward the compartment walls and compartment openings that exist between the loop compartment and the sump elevation of containment. To determine how much of this debris leaves the loop through the openings and how much gets intercepted by loop walls, the lengths each opening and each span of wall are found. The following table illustrates how this was performed to determine the fractional distribution of large debris originating from the Unit 2 Loop A compartment:

Example Distribution of Large Debris from an RCS Loop Compartment

Opening Designation	Passing to Zone #	Length of Opening (ft)	Percent of total opening length
A	111 (sump elev.)	6.42	5.2%
B	108 (sump elev.)	11.58	9.4%
C	108 (sump elev.)	8.00	6.5%
D	109 (sump elev.)	8.00	6.5%
E	110 (sump elev.)	14.92	12.1%
Wall Designation		Length of Wall Span	
W1		32.92	
W2		6.00	
W3		15.30	
W4		14.75	
W5		5.50	
Total Length of Walls and Openings		123.39 ft.	

The resulting distribution logic tree for large debris is depicted below:



Example Distribution Logic of Large-Sized Debris that Originate in RCS Loop Compartment; Distribution due to Blow Down and Pool Fill Transport

Washdown / Sump Recirculation

The approved guidance of NEI 04-07 lacks substantial detail on how to perform washdown and recirculation analyses. The following information provides a complete narrative of the methods, assumptions, software, etc. previously used to perform the analyses. It is expected to continue to be used when revising analyses to account for the reductions in fibrous insulation.

Analytical Methodology

The following outline presents the general methodology for performing the debris transport calculations for the PBNP Unit 2 containment following a Loss of Coolant Accident (LOCA). The methodology follows that outlined in NEI 04-07 and the associated NRC Safety Evaluation Report (SER).

1. Perform steady-state Computational Fluid Dynamics (CFD) simulation for a given break scenario.

2. Post-process the CFD results by plotting three-dimensional surfaces of constant velocity. These velocities will correspond to the incipient transport velocities tabulated in NEI 04-07 for the debris generated in the LOCA scenario.

3. Project the extents of the three-dimensional surfaces of velocity onto a horizontal plane to form a flat contour. Automatically digitize a closed curve around the projected velocity contour and calculate the area within the curve.

4. Compare the area calculated in (3) to the total floor area of the zone containing the particular debris type/size under consideration. This comparison gives the fraction of the floor area susceptible to transport.

5. Tabulate the results of each calculation to determine the total fraction of debris transported to the sump for each LOCA break scenario and each debris type.

Significant Assumptions

The following general assumptions were made in the course of the debris transport calculations.

1. It was assumed that an equal amount of flow is drawn through all modules in each train. (The strainer array has flow control devices).
2. The flow from each break falls uninterrupted to the pool (i.e., the break flow does not impact any equipment, piping or structures). This is conservative for the purposes of flow analysis, and differs from the detailed evaluation of the potential for air entrainment that considers the presence of intervening structures.
3. Spray flow from the two containment spray headers was uniformly distributed across the refueling floor. The openings on and above the refueling floor received spray flow in proportion to the area of each opening.
4. No insulated piping or equipment exists in the sump that would significantly influence flow patterns in the pool during recirculation.
5. Stair treads (there are no risers) on the stairways entering the sump pool were not included in the model. These steps are effective in dissipating the spray flows running down the two stairwells, but do not provide a significant blockage to the horizontal flow patterns in the pool during recirculation.

6. Stairwells are offset as necessary to ensure that stairwell spray flow could be projected onto the water surface separate from the spray flow arriving via the annular gap near the containment liner.
7. The floor drains at each elevation above the pool were assumed to be blocked. Spray flow impacting the refueling floor passed down to the lower levels over the edges of the openings at that elevation in proportion to the perimeter of each opening.
8. Spray flow reaching the level above the sump was directed through the two stairwells and the 3" gap around the periphery of the containment in proportion to their respective areas.
9. It was assumed that the spray flow that would normally enter the refueling cavity enters the accident sump through the two steam generator vault openings. This flow is proportioned between the two (2) steam generator vaults based on their respective areas. This maximizes the analyzed flow velocities by combining with break flow in the loop with the break. The refueling cavity drain discharges near one of the two strainer trains and bypasses the larger quantity of debris remaining on the floor of the loop compartment containing the break.
10. Details of the flow patterns through the 3" gap and through the two stairwells are not modeled. The tapered containment wall and stair steps dissipate the momentum of these streams and the flow patterns entering the pool at these locations are assumed to be uniform over their respective areas.
11. The generic fiberglass insulation debris is assumed to be a low density fiberglass with the same minimum tumbling velocity as NUKON®.

Computational Fluid Dynamics (CFD) Software

Several commercial software programs are used in performing the debris transport calculations. Those that support or perform the computational fluid dynamics are:

I. GAMBIT Version 2.1.6

This program was used to generate three-dimensional solid models of the containment building from the floor elevation to the selected water surface elevation. GAMBIT was also used to generate the computational mesh and to define boundary surfaces required to perform the CFD analysis.

II. FLUENT® Version 6.1.22

FLUENT® Version 6.1.22 was used to perform the CFD simulations. FLUENT® is a state-of-the-art general purpose commercial CFD software package for modeling problems involving fluid flow and heat transfer. It has been used to model flow processes for both government and industry and is one of the CFD software programs used by the NRC.

CFD Model and Boundary Conditions

The CFD model of the flooded portion of the containment was developed using GAMBIT. The model included the SFS strainer module modification including two (2) module trains. The free surface water elevation at the start of recirculation was 3' 2" above the basement floor. The numeric model did not include relatively small objects, such as support columns, pipes, pipe supports, equipment, instrument panels, etc., that are 6" along their longest dimension. Groups of objects with projected dimensions greater than 6" are generally included. In critical areas such as containment sumps and constricted flow paths, objects less than 6" are included.

This meshed model was imported into the FLUENT® CFD software program. The values for each boundary condition and the properties of the working fluid (water) were set in FLUENT®. The two-equation realizable k-model was used to simulate the effects of turbulence on the flow field. The results of the steady-state, isothermal flow simulations included component velocities (x, y and z directions), turbulent kinetic energy and the dissipation rate of turbulent kinetic energy for each cell in the computational mesh.

The following is a description of the boundary conditions used in modeling the PBNP Unit 2 containment sump flow patterns and velocity distributions. Each relevant physical boundary is listed followed by a discussion of the boundary condition applied at that surface.

Solid Surfaces

All of the solid surfaces in the containment building below the modeled water surface, including the walls, floors and structural supports, were treated as non-slip wall boundaries. At these surfaces the normal and tangential velocity components were set to zero.

Water Surfaces

The upper boundary of the CFD model representing the water free surface was set at a water depth of 3' 2" above the floor and maintained constant throughout the CFD simulations. This water surface elevation corresponds to the minimum water level at the start of recirculation and is conservative since actual transport-flows slow as the sump level rises.

It has been postulated that as the water level rises during an actual event, the increased turbulence and/or the vertical velocity vector of the rising surface could cause a non-conservative result. The following discussion illustrates the reason that this does not occur and how the issue is addressed by the simulation.

During the first 30 minutes of recirculation, the inflow to the pool (break flow Q_B plus containment spray flow Q_S) is greater than the outflow through the containment sump, Q_P. The excess of inflow versus outflow will cause the water surface to rise. The speed at which the water surface rises is calculated as:

$$V_S = \frac{Q_B + Q_S - Q_P}{A}$$ where A is the exposed water surface area.

In these simulations, the water surface rise velocity is very small compared to the expected pool velocities which would facilitate transport. Therefore, it is reasonable to assume that flow is steady and the water surface rise is treated as an outflow with a fixed vertical component of velocity where specified to satisfy continuity. This method allows for a quasi steady-state simulation of the flow patterns and velocity levels in the pool at a constant selected water depth.

LOCA Break Flows

Each break / strainer train combination was simulated. Future analyses may curtail the number of combinations if it is determined that one or a few breaks are dominant and limiting.

It was assumed that each break flow falls to the pool water surface without contacting any equipment or structures. The break flow jet accelerates under the influence of gravity as it falls towards the water surface. This is a conservative method to model the break flow as it produces the greatest lateral outflow velocities along the floor.

The initial velocity *V1* of the water jet exiting the break is determined by:

$$V_1 = \frac{4Q_b}{\pi D_1^2}$$

where:
Qb = break flow (ft^3/s)
*D*1 = break inner pipe diameter (ft)

The velocity of the jet at the pool surface *V*2 is determined by:

$$V_2 = \sqrt{V_1^2 + 2gH}$$

where:
g = gravitational acceleration (ft/s^2)
H = vertical difference between break location and water surface (ft)

The diameter of the jet D_2 at the pool surface is determined by:

$$D_2 = \sqrt{\frac{4Q_b}{\pi V_2}}$$

Each break was modeled by a circular velocity boundary surface on the top of the model under the given break location. These surfaces had a diameter D_2 and a flow velocity V_2 was applied normal to this surface. This method reproduces the correct flow and momentum of the jet without requiring the entire jet to be modeled from the origin of the break.

Spray Flows

The flow from the spray header was introduced into the pool through a velocity inlet around the periphery of the containment, steam generator compartments and both of the open stairwells. The spray flow was distributed to each of these openings as appropriate.

The velocities of the sheeting flow across the refuel floor due to containment spray are calculated and any debris deposited is transported to the sump if the calculated velocity exceeds the incipient tumbling velocity.

Debris Size Classification

The initial debris size distributions after pool fill, as provided by the debris generation / blowdown / pool fill analyses, were divided into "small" (dimensions less than or equal to 4") and "large" (dimensions greater than 4"). For the washdown and recirculation transport analyses, these size classes were further subdivided, based on guidance provided by the NEI 04-07, Volume II, and accounts for erosion effects.

A fraction of the large and small debris found in the basement (sump) debris zones is considered erodible into fines which remain suspended indefinitely. The remaining amount of debris may be susceptible to transport if the local flow velocity exceeds the incipient tumbling velocity of that debris type.

Erosion of Debris

A fraction of certain insulation types were assumed to erode into fines that are sufficiently small that the individual fibers or particles stay suspended in the water indefinitely. These suspended fines were assumed to move to the screens at any flow velocity and were therefore, assumed to be on the sump screen for determination of head loss. The remaining fraction of the insulation forms discreet particles which sink to the bottom of the pool and may be transported by the flow if the velocities equal or exceed the threshold velocity for incipient tumbling of that material. Erosion factors were obtained from the available test data found in available literature and used to quantify the amount of fines generated from the LOCA blast and later erosion that would arrive at the screens.

Data from NUREG/CR-6808, Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance, for air jet testing of low density fiberglass (LDFG) at Colorado Engineering Experiment Station Inc. (CEESI), indicated an average of 20% of the insulation was classified as "non-recoverable" (i.e., fines). The same document summarized a single test on LDFG at the Ontario Power Generating (OPG) testing facility using heated, pressurized water. The quantity of fines was measured as 47%.

Due to the more numerous tests at the CEESI facility (and consistent with the preference toward air jet testing over water jet testing for establishing the destruction ZOI), more weight was given to the CEESI test results and an average of 30% of low density fiberglass insulation is assumed to be disintegrated into fines. These fines would remain in suspension and be filtered out by the sump screen. This fraction was applied to both the NUKON® and fiberglass debris types.

CalSil was also tested at the OPG facility. The quantity of debris too small to be collected was termed "dust" and its mass was calculated by subtracting the collected mass from that of the initial target insulation. NUREG/CR-6808 indicates that the maximum mass of dust from seven tests was approximately 28% of the initial mass. Since some of the smaller, discrete fragments would further dissolve, it was assumed that a total of 35% of the initial amount of CalSil disintegrates into fines, remains in suspension and is filtered out by the sump screen.

A fraction of the smaller CalSil fragments, such as those blown into the containment by the initial break energy, would dissolve in the heated water of the pool. NUREG-6772, Separate-Effects Characterization of Debris Transport in Water, Section 3.3.1, summarizes tests on 10 gm (0.35 ounce) samples of CalSil placed in heated water with and without stirring. From 46% to 76% of these smaller fragments disintegrated as a suspension in the water.

It was assumed that only a small percentage of large chunks of CalSil would disintegrate, so the total fraction of the initial amount of CalSil converted into a suspension would be 35%.

NextEra also accounted for mineral wool, Insulbatte (Temp-Mat®) and asbestos, and these insulation types. These may also be subject to disintegration into fines which stay suspended in the water.

NUREG/CR-6772, Table 1.1, indicates that some types of mineral wool are similar to Kaowool™ and that Kaowool™ is a low density fiberglass. Therefore, it was assumed that the percentage of mineral wool fragmented into fines, suspended in the water pool and filtered out by the sump screens is the same as used for fiberglass, (30%).

Insulbatte (Temp-Mat®) was tested in the CEESI facility and NUREG/CR-6808, Section 3.2.1.2, indicates a damage pressure of 17 psig was recommended by the Boiling Water Reactor Owners Group (BWROG) for unjacketed insulation. Similar testing for Knauf fiberglass and NUKON® fiberglass indicated the recommended damage pressures were 10 psig for both insulation types.

This indicates that the fiberglass insulation was easier to damage. To be conservative, the extent to which Insulbatte disintegrates into fines was assumed to be the same as for fiberglass (30%).

There has been no testing with asbestos insulation, likely due to the special handling requirements associated with the hazardous material. Without explicit knowledge of material properties compared to other insulation types, it was conservatively assumed that 50% of asbestos insulation is fragmented into fines, suspended in the water pool and filtered out by the sump screens. This assumed percentage is higher than used for any other type of insulation due to the lack of test data or related information.

The flume testing described in the response to Question 4 introduced a scaled quantity of fines based on a percentage of all of the fibrous debris generated in containment, including debris calculated to be retained in other compartments and debris expected to be transported to the sump. There was no reduction in the fines inventory used in the testing due to a calculated transport fraction.

Debris Transport Characteristics

Settling velocities and incipient tumbling velocities for the debris insulation types were obtained from NUREG/CR-6772 and as summarized in NEI 04-07, Table 4-2. These velocities were applied to the fractions of debris insulation types that remain after erosion during the blowdown and washdown phases.

Calculation of Debris Transport Fraction

Using the results of the CFD simulations, velocity isosurfaces and streamline plots were generated for use in predicting debris transport. Plots were generated corresponding to areas where velocities are equal to or greater than the velocities associated with incipient tumbling of the debris found in each zone. The velocity plots were obtained by projecting down to the containment sump floor the maximum lateral extent of a three-dimensional volume in which the velocities were equal to or greater than the selected incipient tumbling velocity. This method accounts for and bounds velocities at all elevations in the pool.

To determine the transport fraction of debris, the velocity contours were examined for isolated regions that were not contiguous with the strainer modules. Streamline and vector plots were used to identify isolated eddies that had velocities higher than the incipient tumbling velocity, but did not contribute to debris transport from the zone to the strainers. These vectors were also used to identify regions of the velocity contours that, while they may have been contiguous with the strainer, the flow was directed away from the strainers. These areas were subtracted and did not contribute to the recirculation transport fraction.

Overlays of the remaining velocity contours with the zone definition plots were used to determine the floor area which would be susceptible to transport for each break location. The fraction of the zone floor area that is susceptible to transport constitutes the recirculation transport fraction for each debris type. The total fraction of debris transported to the strainer from each zone is determined by the following equation:

Fraction of Debris Transported to Strainer per Zone
= Erodible Fraction + (1-Erodible Fraction) x Transport Fraction

This process is applied for each debris type, in each zone and for each break analyzed.

Results (Including Transport Fractions and Total Quantities of Debris)

Due to the pending large scale removal of fibrous debris sources from containment, the debris generation and transport analyses are being re-performed using the methodologies, assumptions and modeling described above. The results of this effort will be completed by December 18, 2009, consistent with the milestone provided in the June 12, 2009, letter from NextEra to the NRC (ML091660326).

Debris Interceptors

Although previously installed in Unit 1, debris interceptors (DI) are no longer being pursued as a credited solution for reducing debris reaching the sump strainers.

The debris interceptors installed in Unit 1 have three significant components:

- The DIs are vertical panels of bar grating that are covered almost entirely by ¼" perforated plate from the floor to a level above the maximum flood level of containment. These panels completely surround the strainers, separating them from the RCS compartments. These DIs feature a 4" high full width gap without perforated plate and with minimal obstructions that is located below the minimum flood level of containment. This gap forms a submerged weir and is sized to ensure that the sump screens cannot be starved of flow, even if all of the perforated plate would be completely blocked by debris.
- A pipe extension that diverts water draining from the refueling cavity (which may contain some small suspended debris) away from the vicinity of the strainers to a location upstream of the main debris interceptors.
- Metal curbing around part of the perimeter of the refueling floor (approximately 40% of the perimeter). This curbing prevents washdown water that may contain entrained fines from falling downstream of the main DIs. The water is diverted instead across the refueling floor to un-curbed locations (such as the refueling cavity, or the portion of the refueling floor perimeter that is not curbed.

NextEra is not crediting the DIs and some or all of them may be removed at a future date. In the interim, their presence is not being modeled in the various transport analyses. If it is postulated that the DIs do not retain debris and are completely ineffective, then they would also have no effect on the flow distributions through the containment sump pool. Conversely, if it is postulated that they retain debris to the point that they alter sump flow patterns, then their net effect would be beneficial in reducing the quantity of debris delivered to the strainers. Therefore, it was determined that neglecting them in the transport modeling is conservative and acceptable.

Debris Settling

As described above, debris characterized as "fines" are assumed to remain in suspension indefinitely. "Small" and "large" debris sizes were modeled and transported if the calculated flow velocities exceeded the incipient tumbling velocities. Settling, though known to occur, was not explicitly modeled. Settling phenomena were accounted for in the design and conduct of the strainer qualification flume testing.

Question 4

Please provide the following head loss and vortexing testing-related information.

a) Information requested by the NRC staff's revised content guide that was not previously submitted due to the testing being incomplete, or that changed during subsequent testing.
b) Flow rates in the flume
c) Scaling factors
d) Debris amounts added to the testing apparatus, and debris size distributions for added fibrous debris
e) Debris preparation and introduction methods which ensure prototypical debris transport and bed formation

NextEra Response

a) A review of both the Staff's guidance and Reference (1) found one item not previously provided:

"3.f.4. Provide a summary of the methodology, assumptions, and results of prototypical head loss testing for the strainer, including chemical effects"

Methodology

Three tests were performed:

1. Differential pressure testing of the clean proto-type strainer
2. Transport testing of miscellaneous debris types
3. Design basis debris load testing

The first test established a baseline differential pressure for the test strainer and associated piping and connections. The second test demonstrated the latent debris types (e.g., tie wraps, tape, labels, foreign material exclusion plugs) that were subject to transport in the sump pool flow streams. The third test was designed to establish a maximum differential pressure for a hypothetical worst case debris loading. The results of the test established a maximum upper bound for debris quantity.

By first adding the lightest, most transportable debris and subsequently introducing progressively heavier, less transportable debris, the test was designed to ensure the establishment of a "worst case" thin bed (see size distribution and sequence response to Question 4(d), Page 20. The more transportable debris was permitted to progress to the screen without the presence of heavier debris that may filter it out of suspension. The addition of the heavier debris was observed to stir up deposits of the lighter debris types that had previously settled to the floor of the test flume.

The test was also designed to demonstrate the effects of a circumscribed bed, if it was possible to form such a debris bed.

The general conduct of the test involved recirculating water through the test strainer while adding debris to the test flume and permitting the debris to transport to the strainer in a prototypical manner under the influence of the flow stream. The differential pressure across the strainer was continuously measured and the flume was permitted to recirculate to ensure quasi-equilibrium was reached between debris additions.

After all debris had been introduced and permitted to recirculate overnight to reach an equilibrium differential pressure, chemical surrogates were added to the flume to simulate the postulated formation of insoluble precipitants while the differential pressure continued to be monitored for trends.

Design of the Test Flume

The flume was designed to reflect a prototypical flow stream velocity. The following describes the analytical steps used to define the dimensions of the test flume:

1. Use the CFD post-processing software to numerically seed each active module train face with mass-less tracer particles (mass-less tracer particles show the direction of the flow at every point along their path).
2. Back-calculate the trajectory of the particles to define streamline traces to each module. (This identifies the path the water follows to each strainer module face.)
3. With the water path to each module identified, use the CFD post-processing software to define vertical planes at 1' increments from the module train, along the paths defined in Step (2).
4. Trim each plane such that the velocities within that plane are those which convey water to the module.
5. At each 1' increment from the module train, record the cross section average of the velocity magnitude across the plane. If the paths diverge around objects in the flow, follow each bifurcated path individually. Record these averages over a total of 20' from the module train.
6. Conduct Steps (1) through (5) for each of the four trains in the array.
7. Calculate the weighted average of the four flow streams at each 1' increment. The average at each increment is weighted by twice the fastest velocity at the increment under consideration in order to incorporate conservatism into the calculation.
8. Create a plot of the calculated weighted average velocity defined in Step (7) vs. incremental distance from the module train.
9. Using engineering judgment, create up to ten linear line segments which conservatively represent the velocity trends over the 20' distance.
10. Calculate the width of the test flume at each line segment break using the following expression:

    $Q = VA$

    Where,

    Q = Total flow to test module (ft^3/s)

    A = Flume cross sectional area (ft^2)

    V = Weighted cross sectional average velocity (ft/s)

    and,

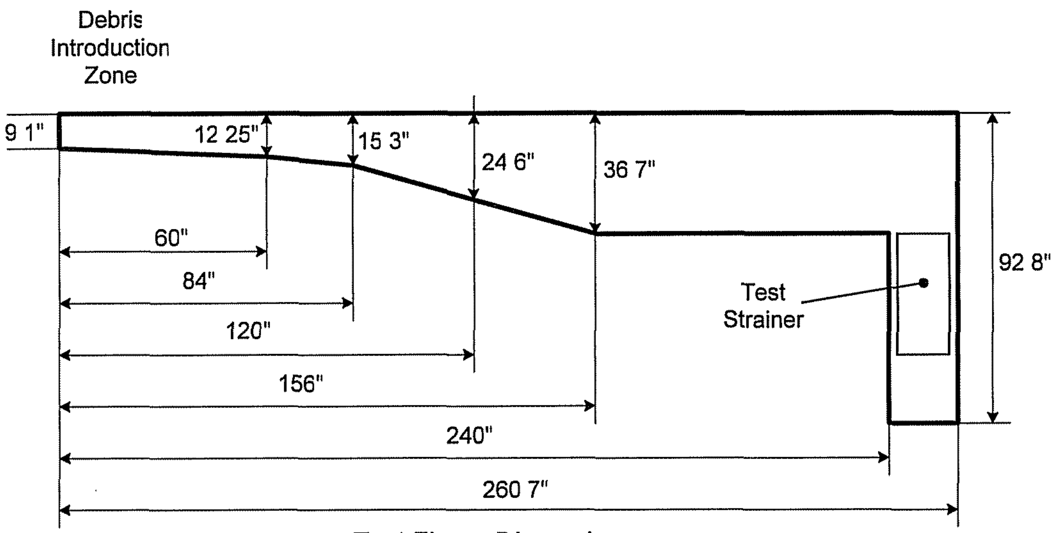
    $A = WH$ Where: W = Flume width (ft)

    H = Water surface height in the test flume (ft)
11. Create a table of flume width vs. line segment length to be used in defining the shape of the flume.

The transition of the flume near the test strainer module is defined by the trajectory of the water as it approaches the modules in the prototype installation. These flow patterns are calculated in the CFD debris transport analysis.

The approach described above results in a test flume profile that replicates the most limiting (i.e. most turbulent) flow configuration expected in the actual plant. Weighting by twice the highest velocity within a flow stream and constraining the performance of the test to a constant low level (actual plant sump level would continue to rise) ensures that the velocities obtained in the test flume are conservatively high, and that the turbulence induced is greater than that expected under actual plant conditions.

The resulting flume dimensions used for the test are depicted below:



Test Flume Dimensions

The sharp turn at the end of the flume adjacent to the strainer is a result of the test facility configuration. However, it approximates the direction of debris entrained flow toward an edge of the strainer, similar to what is expected in the installed configuration. In the installed configuration, several modules are linked together such that the approaching flow progresses primarily toward the exposed sides of the modules and not from the ends.

Additionally, as evidenced by photographs of the test strainer during and after drain-down of the test flume, the debris cake was evenly formed over the entire surface of the strainer. There was no apparent disproportionate distribution due to the sharp turn in the flume.

<u>Water Used in Flume</u>

The head loss tests were conducted with city domestic (tap) water at a temperature of approximately 100°F to 120°F.

The pH of the water in the test flume was not intentionally controlled. The pH measured during tests prior to the addition of chemical effects surrogates ranged from 6.44 to 6.53. After the addition of the basic chemical effects surrogates, the pH increased to 8.82.

Prototype Test Strainer

The full strainer arrays consist of 14 modules each. The prototype test strainer was a single module that had originally been procured as a spare replacement module. As such, it was dimensionally identical to any module installed in the plant.

The surface area of the test module was 135.9 ft^2.

Turnover times, stabilization time

The total volume of the flume and connecting piping was 2,460 gallons. At the targeted flow rate of 170.7 gpm, the turnover time was 14.4 minutes.

A minimum of five (5) flume turnovers elapsed after introduction of each of the fine, small and large fibrous debris inventories.

A minimum of two (2) flume turnovers elapsed following each batch addition of chemical surrogate.

Recirculation continued and the differential pressure (head loss) was monitored for a minimum of fifteen (15) flume turnovers following addition of all of the chemical surrogates.

Chemical surrogates

AluminumOxyHydroxide (AlOOH) was used as a chemical surrogate for the expected Sodium Aluminum Silicate ($NaAlSi_3O_8$). The surrogates were prepared in accordance with the approved guidance of WCAP-16530-NP.

The maximum quantity of $NaAlSi_3O_8$ that may be generated in the PBNP sump was determined to be 194.1 Kg. This was increased to 197 Kg (434.3 lbs) as a contingency for possible future discoveries. The stoichiometric equivalent is 99.9 lbs of AlOOH. This quantity was multiplied by the test scaling factor of 7.53% to obtain 7.52 lbs, and an additional 1% was added to account for possible solubility effects. The target quantity of AlOOH was therefore 7.60 lbs.

Assumptions

Flume testing of various postulated miscellaneous latent debris demonstrated that the debris would sink and was not transportable in the flow stream (labels, cable ties, sanding disks, paper, plastic pipe caps, gloves, etc). A small number of items were observed to float on the surface and transport (e.g. plastic FME plugs, duct tape, masking tape, nylon rope, danger tape, a polyethylene bag, a "hot spot" tag, and various pens). To conservatively bound the effects that such latent debris may have on a strainer array, it was assumed up to 100 ft^2 of active screen surface would be blanketed by such debris. To account for this effect, the flume flow rates were increased accordingly. Refer to the Results section below for additional detail on scaling factors.

Results

At a flow rate of 150 gpm and 116°F, the clean strainer head loss directly observed during the test was 0.066'. When the flow was increased to 175 gpm at 118°F, the clean strainer head loss was 0.090'. This head loss is subtracted from the debris loaded test result to determine the head losses associated with the debris bed during debris loaded testing. Refer to Question 8 for the clean strainer head losses of the installed strainer array.

The temperature and flow rate corrected debris loaded strainer head loss for the design basis debris load test was 6.45' at a reference temperature of 113.6°F at a flow rate of 170.7 gpm. The peak loss occurred after the design basis fibrous and particulate debris was placed in the test flume and prior to any chemical introduction.

The temperature and flow rate corrected debris loaded strainer head loss at test termination (100% of chemicals introduced and 15 flume turnovers) was 3.64' of water at 175 gpm at a temperature of 113.6°F.

The suspended debris in the test flume prevented imaging of the test strainer during the conduct of the test. However, photographs of the test strainer module after the recirculation pumps were secured and after drain-down of the test flume had started indicated that a relatively uniform "thin bed" of debris was formed. No significant bridging of the strainer disks (indicating a "circumscribed bed") was evident.

b) Flow rates in the flume

The flow rates for the clean strainer test ranged from 125 gpm to 225 gpm to generate a head loss vs. flow curve.

The flow rates for the debris loaded test varied slightly through the course of the test as the flow was adjusted to remain constant as the debris bed developed and aged. At the highest recorded head loss, the flow was 170.4 gpm. At test termination, the flow rate was 175 gpm.

c) Scaling factors

The full scale arrays have a total active strainer surface of 1,904.6 ft^2. To account for potential debris blanketing by sheet-type latent debris, 100 ft^2 was deducted from this active surface area for a net area of 1,804.6 ft^2.

The test strainer had an area of 135.9 ft^2. This resulted in a test scaling factor for debris and flows of:

$F = 135.9\ ft^2 / 1804.6\ ft^2 = 7.53\%$

The design basis flow rate for the strainer arrays is 2,200 gpm. Therefore, the minimum test flume flow rate was 2200 gpm x 0.0753 = 166 gpm.

The flume water depth was set at the minimum design submergence for the screens and not varied during the additions of particulate and fibrous debris. In order to prevent loss of chemical surrogates from the flume, it was necessary to allow the level to rise minimally (~1.4") with the addition of chemical surrogates. Actual containment sump levels would continue to rise significantly during the first approximately 30 minutes of containment sump recirculation. Therefore, the low water levels of the test were conservative in that they maximized flume velocity and minimized screen submergence.

d) Debris amounts added to the testing apparatus and debris size distributions for added fibrous debris

The amount of each type of debris, as well as the sequence added, was as follows:

Batch 1: 25% of Latent Fibrous Debris (NUKON® fine fiber, 0.15 lbm)

Batch 2: 100% of Cal Sil (47.1 lbm)

Batch 3: 100% of Latent Particulate, Dirt and Dust (9.7 lbm)

Batch 4: 100% of Aluminum, Alkyds, and Epoxy Coatings, Acrylic Powder (142.6 lbm)

Batch 5: 100% of Zinc Coatings, Tin (85.1 lbm)

Batch 6: 100% of Fine NUKON® Fibers (3.2 lbm)

Batch 7: 100% of Fine Ceramic Fibers (11.7 lbm)

Batch 8: 100% of Owens Corning Fine Fiberglass Fibers (3.6 lbm)

Batch 9: 100% of Temp-Mat® Fine Fibers (6.0 lbm)

Batch 10: 100% of Mineral Wool Fine Fibers (10.1 lbm)

Batch 11: 100% of Degraded Epoxy Coatings, Acrylic Chips (93.2 lbm)

Batch 12: 100% of Small NUKON® Fibers (0.7 lbm)

Batch 13: 100% of Small Owens Corning Fiberglass Fibers (2.9 lbm)

Batch 14: 100% of Small Temp-Mat® Fibers (1.3 lbm)

Batch 15: 100% of Small Mineral Wool Fibers (4.1 lbm)

Batch 16: 100% of Large NUKON® Fibers (1.3 lbm)

Batch 17; 100% of Large Temp-Mat® Fibers (4.8 lbm)

e) Debris preparation and introduction methods which ensure prototypical debris transport and bed formation

For details about the preparation of the surrogate materials, their size distributions (fines, smalls, larges and intact), and the technical basis for the use of the various surrogates, refer to Performance Contracting Inc., letter to NRC, dated March 25, 2009, PCI-6016-02.01, Attachment 3, Sure-Flow® Suction Strainer – Testing Debris Preparation and Surrogates, SFSS-TD-2007, Revision 4 (Proprietary) (ML090900476).

For the design basis test, all batches, except for Batch 1, were introduced at the far end of the flume (the "drop zone"), upstream of the strainer module. Batch 1 was introduced along the length of the flume prior to the start of the recirculation pump.

It has been noted that Batch 1, being introduced prior to the start of the recirculation pump, may have introduced non-conservatism into the test protocol. Introduction of a portion of the debris representing latent (pre-existing) fibers into the sump prior to starting the test recirculation pumps was intended to more accurately represent the expected behavior of debris resident in the containment during the sump pool fill phase. Introducing this portion over the length of the flume, rather than at the "drop zone" was intended to more accurately simulate the expected distribution over containment.

The debris introduced prior to starting the recirculation pumps was limited to only fine fibers of NUKON®, which remain suspended "indefinitely", and which would be subject to transport in any flow stream regardless of the velocity (i.e. no threshold for incipient tumbling velocity). Therefore, introduction prior to the start of the recirculation pumps should not be a concern. In any case, the portion so distributed represented such a minor fraction of the total fibrous debris introduced (0.15 lbs of the total 3.45 lbs of fine NUKON® fiber and an even smaller fraction of the total fines and total fiber in the test) into the flume that this deviation in the otherwise consistent introduction protocol had a negligible effect on the results.

To minimize non-prototypical turbulence caused by the introduction of large quantities of debris into the flume, an inclined ramp was built that permitted pouring out the pre-wetted debris slurry onto the ramp, and allowing it to washdown the ramp into the flume. While this reduced the turbulence caused by pouring the debris in a free falling column of water, some disturbance of the settled debris was still observed with each introduction.

Question 5

At the beginning of recirculation for a small-break loss-of-coolant accident (SBLOCA), the strainer stacks are submerged by about two inches. The supplemental response stated that buoyant debris would not be present following a loss-of-coolant accident (LOCA) (based on the first tests performed at Alden Research Laboratory (ARL) and that, therefore, air ingestion through the debris on the strainer screens would not occur. However, NRC staff present at the ARL testing noted that the debris was added after being mixed together and then mixed with water. This test may have not been a prototypical test to determine whether buoyant debris can occur. The phenomenon of buoyant debris should be addressed.

NextEra Response

The design basis submergence for the PBNP strainers is independent of the size of a LOCA. The 2" minimum submergence cited is therefore applicable to the full range of postulated LOCA events.

The testing witnessed by NRC staff present at Alden Research Laboratory (ARL) was conducted in 2005 and 2006. Since that time, considerable industry and NRC efforts have been invested in developing a test protocol that is considered more conservative and appropriate. The tests being discussed in this response were performed in July 2008 and were conducted in accordance with the later protocol. This later protocol also pre-mixes the various debris types in water prior to introducing the debris to the test flume.

The practice of pre-mixing debris is considered conservative and appropriate because it enhances the distribution of the debris in the water and tends to free individual fibers that may otherwise "clump" together and provide less conservative results than individual fibers and small clusters of fiber. This increases the likelihood of forming a limiting thin bed with a high head loss during the test.

While the debris of each size and material type were pre-mixed with water, different debris material types and different debris sizes were pre-mixed and introduced into the flume separately.

The potential for floating debris causing a blanketing effect and leading to air ingestion at the top of the screen is considered very unlikely for several reasons:

1. While the level of the containment sump is at a minimum 2" at the start of sump recirculation, it continues to increase over the course of approximately 30 to 40 minutes as additional RWST volume is transferred to the containment sump by containment sprays. The final submergence level would be a minimum of 14.6" deeper when the RWST is depleted to 12% level, and additional submergence can be expected as water held up as spray droplets, steam and sheeting water drain to the sump when containment spray is terminated. By comparison, the sump turnover rate, based on the volume at the minimum recirculation level of 38", or approximately 154,000 gallons, and the maximum design sump outflow rate of 2,200 gpm, is 70 minutes. Therefore, the screens have substantially greater submergence well before a single turnover of the sump (i.e. transport of debris toward the screens) has occurred.
2. Insulation dislodged by a postulated energetic two phase jet would tend to be wetted by the same jet.

3. The debris would have a considerable “soak time” in the stagnant hot sump water prior to initiation of sump recirculation. The low viscosity and low surface tension of the hot water enhances rapid wet-out of the debris and ensures it occurs prior to the start of sump recirculation.
4. PBNP does not have closed-cell insulation types (e.g. microtherm, Min-K, or anti-sweat foam) in the LOCA ZOIs. Miscellaneous debris types (e.g. electrical tape, tie-wraps, labels, etc.) were also tested for transport characteristics during the flume testing and found not to float.

Question 6

The supplemental response did not consider the potential effects of water from the break or from spray drainage falling near the strainer. Especially during the period of relatively small submergence, and possibly at times for which there are other sump pool levels, the falling water could entrain air near the strainer resulting in the air being drawn through the strainer and into the emergency core cooling system pump suction header. This potential post-LOCA phenomenon should be considered and addressed.

NextEra Response

At PBNP, there is no potential for water cascading from upper levels to fall directly on a strainer assembly. An analysis comparing the rise velocity of an air bubble originating at the floor of containment to a height above the strainer with the horizontal velocity of water moving toward the strainers found that bubbles originating 2” or more from a strainer cannot be ingested by the strainer.

It has been verified that areas where water may cascade into the sump pool are located significantly greater than 2” from the strainers. In one case, the planned extension of the strainer array by an additional three modules could result in the array being below the reactor cavity drain located above. Modifications will include extending this specific drain away from the strainers, or installation of an impingement device between the strainers and the drain to prevent air ingestion. In one other location, there is the potential for distributed droplets from containment spray to pass down several flights of an open stairwell and impinge on the pool surface immediately above a strainer. This distributed rain-like flow is judged to not be a source of entrained air bubbles.

Question 7

The supplemental response stated in one place that observations for vortexing will be accomplished during the head loss testing for the future. In another area, the supplemental response stated that the assessment of vortexing was based on empirical observations rather than a calculation (presumably during testing which had already been conducted). These two statements appear to be contradictory. The final vortexing assessment should provide the test conditions under which the observations occurred and discuss how these conditions are either prototypical or conservative with respect to expected plant conditions.

NextEra Response

The observations for vortexing were performed during the testing described in the responses to Questions 3 and 4.

The installed strainers are PCI Sure-Flow® strainers which incorporate a flow control device that ensures even flow distribution among all of the strainers in the array. The test strainer module was dimensionally identical to one of the 14 strainer modules of the complete strainer array and the flow was conservatively higher than 1/14 of the design flow for the strainer array. Therefore, the test strainer was prototypical while the flow rate was conservative.

The submergence level of the test strainer was controlled to remain constant at 2" throughout the addition of fibrous and particulate debris and permitted to rise minimally (~1.4") with the addition of the chemical surrogates. In contrast, the actual post-accident sump levels would rise over the first approximately 30 minutes of sump recirculation and provide additional margin against vortex formation. Therefore, the submergence level of the test strainer was conservative.

Upon completion of fibrous insulation abatement, the potential debris loading in the containment will be bounded by the testing that was completed. Therefore, the debris loading of the test was conservative.

At no time during clean strainer head loss or debris loaded head loss testing was vortex formation observed.

Question 8

The clean strainer head loss (CSHL) value provided in the submittal was stated to be for hot sump conditions. A value for CSHL for the postulated minimum sump temperature should be provided.

NextEra Response

The expansion of the strainer arrays to include three additional modules (for a total of 14 modules) required re-evaluation of the clean strainer head losses. Therefore, the following information supersedes the previous response in Reference 1, and was obtained from Table A-1 in Enclosure 2 of this submittal.

The calculated clean strainer head loss (including losses from associated piping and fittings up to the containment outlet) at 212°F and the design flow rate is 0.41'.

The corresponding calculated head loss with 72°F sump water is marginally higher at 0.59'.

Question 9

The licensee assumed that all debris generated by a LOCA transports to the sump. However, no size distributions for the various debris types expected to arrive at the strainer was provided. Size distribution is an important factor in debris bed formation and is therefore required to perform and document a valid head loss test. Size distributions for debris expected to arrive at the strainer should be provided.

NextEra Response

The requested information will be evident as the end result of the final debris generation and transport analyses. While these analyses have been performed for the existing insulation configuration, they have not been completed with regard to the fibrous insulation replacement plan approved by the NRC, June 30, 2009 (ML091800430), for PBNP Units 1 and 2. The following table, Unit 2 Steam Generator B Crossover Leg Nozzle with B Strainer Train Operation, was developed using the existing analyses and deducting fibrous insulation to be replaced with RMI. The table reflects the single most limiting break that was identified for the existing insulation configuration.

The debris quantities projected for the final configuration are based on the estimated results of the existing analyses after they are revised to incorporate insulation replacements and the addition of three strainer modules per train. The quantities of coatings have been reduced as discussed in the response to Questions 15 and 16. The potential presence of miscellaneous debris was accounted for by the use of an assumed "sacrificial area" of 100 ft^2 when scaling the flow rate of the flume for the test strainer (see the response to Question 4 for the discussion of scaling factors). The assumed latent debris total, 150 lbs, has been conservatively maintained despite sampling data which indicates actual values are much lower.

The table below also contains the quantities of debris used in the July 2008 screen qualification flume test. For ease of comparison, all test quantities are presented as in full scale equivalents. From this comparison, the planned insulation reductions will result in a total fibrous debris inventory that is substantially less than that which passed in the successful screen test.

Although not immediately apparent, the assumed quantity of latent debris fiber is bounded by the test. It was assumed that 22.50 lbs of latent fibers are present in containment. However, the test plan only introduced a scaled equivalent of 6.64 lbs of NUKON® fines to the flume to account for the latent fibers. This reduction between the quantities assumed to exist in the containment and that which was introduced was intended to account for expected debris interceptor performance. Since completion of the strainer testing, NextEra has elected to forego crediting debris interceptors. The difference between these quantities must now be reconciled through the removal of fibrous insulation.

Following the initiation of flume flow, 17.71 ft^3 of NUKON® fines were introduced in-stream to account for NUKON® insulation. The quantity of generated NUKON® insulation is planned to be significantly reduced or eliminated entirely. Considering the as-fabricated NUKON® density, 2.4 lb/ft^3, the in-stream NUKON® introduction represents 42.5 lbs of NUKON® fines which offsets the difference between the assumed latent fiber quantity and the specifically tested quantity of latent fiber.

NextEra plans to complete the analyses reflecting the quantities of debris expected to arrive at the strainers by December 18, 2009, as previously stated in the June 12, 2009, letter from NextEra to the NRC (ML091660326). Although it is possible that the bounding break location may change, the quantities transported to the strainers are expected to remain bounded by the test results.

Unit 2 Steam Generator B Crossover Leg Nozzle with B Strainer Train Operation

Debris Types	Size Distributions	Analytical Results for Current Configurations		Projected Configuration		Tested Debris Quantities ft^3 (scaled up)
		Generated Debris (ft^3)	Debris Transported to Strainer (ft^3)	Generated Debris (estimated ft^3)	Debris Transported to Strainer (estimated ft^3)	
Asbestos (Ceramic Fiber surrogate)	Large Small Fines Small Fine	0 116.07 n/a n/a	 n/a 10.53 58.04	0 16.5 n/a n/a	 n/a 1.50 8.52	n/a n/a 15.54 (fiber) 6.77 (particulate)
NUKON®	Large Small Fines Small Fine	93.97 140.95 n/a n/a	28.19 n/a 14.92 70.48	0 0 n/a n/a	0 n/a 0 0	7.19 n/a 3.87 17.71
Temp MaT®	Large Small Fines Small Fine	35.76 53.66 n/a n/a	21.36 n/a 5.68 26.83	0 0 n/a n/a	0 n/a 0 0	5.40 n/a 1.46 6.75
Fiberglass	Small Fines Small Fine	114.70 n/a n/a	n/a 27.32 34.41	24.5 n/a n/a	n/a 5.84 7.34	n/a 7.00 8.69
Mineral Wool	Small Fines Small Fine	221.96 n/a n/a	n/a 26.80 66.59	0 n/a n/a	n/a 0 0	n/a 6.81 16.77
Latent Fibers	Fine	22.50 lbs	22.50 lbs	22.50 lbs	22.50 lbs	6.64 lbs
Cal-Sil	Small Fines Small Fine	83.87	n/a 9.08 29.36	7.2	n/a 0.78 2.52	38.47
Latent Particulate	Particulate	127.5 lbs	127.5 lbs	127.5 lbs	127.5 lbs	127.5 lbs
Zinc Coating	Particulate	2.47	2.47	2.25	2.25	2.47
Aluminum Coating	Particulate	0.14	0.14	0	0	0.14
Alkyd Coating	Particulate	6.86	6.86	6.86	6.86	6.86
Unqualified Epoxy Coating	Particulate	5.05	5.05	5.05	5.05	5.05
ZOI Epoxy Coating	Particulate	8.37	8.37	3.58	3.58	8.37
Degraded Epoxy Coating	Chips	13.16	13.16	13.16	13.16	13.16
Misc. Debris	Film	189 ft^2	n/a	152 ft^2	59 ft^2	100 ft^2 Sacrificial Area

From the above table, the total the volume of fibrous insulation debris transported to the strainers in the current configuration is 391 ft^3. After the projected reductions have been completed, it is estimated that this total will be 23.2 ft^3. The scaled total quantity of fibrous insulation debris used in the screen qualification test was 97.2 ft^3.

Question 10

Based on recent testing, it was reported that a debris interceptor would be installed that will prevent 75 percent of the debris from reaching the strainer. The amount of debris passing the interceptor should have been, or should be, evaluated considering the potential water levels above the interceptor, debris sizes, debris types, etc. The debris used in testing should match the characteristics of the debris that is expected to pass the interceptors. Therefore, the validity of the 75 percent efficiency value for the debris interceptor should be addressed and also stated to be reflected in debris quantities used in strainer testing, if applicable.

NextEra Response

Upon further evaluation of the DI qualification test results, and in consideration of additional development that may place a higher performance requirement on the DIs than they are capable of supporting, NextEra has elected to forego crediting DIs in the final resolution of these issues. The DIs previously installed in Unit 1 may eventually be removed, particularly since their presence creates additional complexity and postulated flow conditions in the transport analyses.

Question 11

The supplemental response did not provide an adequate response to the revised content guide question on the ability of the strainer to accommodate the maximum debris load. The supplemental response stated that debris beyond that collecting on the strainer would collect in the free volume in the lower level of the containment. The intent of the question is to ensure that the strainer either has a large enough area to prevent circumscribed bed formation, or that the formation of a circumscribed bed will not result in excessive head loss. Alternatively, a properly conducted test could show that a circumscribed bed will not result even from the maximum potential debris load. Please re-address this content guide question, given the above guidance.

NextEra Response

The test performed and described in the responses to Questions 3 and 4 was designed to favor the formation of a circumscribed bed if one could be formed. By structuring the debris additions to progress from the smallest debris to the largest debris, using prototypical or bounding high transport flow velocities, all debris that might be transported to the strainer were transported. Larger debris did not impede the transport of smaller debris. Conversely, the later addition of larger debris could (and based on the recorded data apparently did) disturb and re-suspend previously settled fine debris. As a result of the test protocol, the measured head loss results reflect the formation of a circumscribed bed if one could be formed.

As noted in the response to Question 4, post-test photographs of the test strainer found no indication that a circumscribed bed had formed.

Question 12

The supplemental response indicated in several places that a thin bed would not likely form on the complex Performance Contracting Incorporated (PCI) strainer. Based on several tests of PCI strainers that have resulted in a relatively thin filtering bed, and the licensee's potentially challenging debris loads in terms of thin bed formation, the staff believes that the thin bed should be evaluated for the new Point Beach strainer configuration. Please justify the conclusion that such a bed would not form.

NextEra Response

The test performed and described in the responses to Questions 3 and 4 was designed to favor the formation of a thin bed, if one could be formed. By structuring the debris additions to progress from the smallest debris to the largest debris, using prototypical or bounding high transport flow velocities, fine fibrous debris that could be transported to the strainer were transported. Larger debris did not impede the transport of smaller debris. Conversely, the later addition of larger debris appears to have disturbed and re-suspended previously settled fine debris, based upon recorded data. As a result of the test protocol, the measured head loss results reflect the formation of a thin bed, if one can be formed.

As noted in the response to Question 4, post-test photographs of the test strainer suggest that a thin bed formed during the test.

Question 13

The submittal references 38 inches as the maximum allowable head loss. Based on recent test results described to the NRC in a phone call with the Point Beach licensee, it appears that this value may be too low. Please state the final maximum allowable head loss and reflect this value in net positive suction head calculations and structural evaluations.

NextEra Response

The replacement strainer assemblies were originally designed to operate with a debris loaded head loss of 38" or less. This was based on the available net positive suction head (NPSH) margin under hot sump conditions at the start of containment sump recirculation. Later developments led to an understanding that while the sump cooled and the available NPSH increased, the differential pressure (ΔP) across the screens could also increase significantly because of higher head losses of the more viscous water passing through the debris bed.

As a result, the design differential pressure of the strainers and related piping and supports has been increased to 10'. This is believed to be the maximum differential pressure justifiable without a complete redesign and replacement of the strainer modules.

Enclosure 2 provides the calculation of total head loss through a debris loaded screen assembly at various temperatures. The calculation is based on the results of prototypical screen testing performed with a debris loading that is conservative for the final anticipated configuration of the PBNP containments.

The results of this calculation demonstrate that if the sump is permitted to cool excessively with the high design flow rate, the 10' differential pressure limit could be exceeded. Therefore, one or more of the following three measures will be implemented to ensure that this does not occur: Limiting long-term containment sump cool down; requiring long-term sump flows to be reduced prior to cooling down below the high flow/low temperature limit, or re-performing the screen qualification testing with a debris mix representative of that which could exist after completion of the planned insulation abatements.

The maximum allowable head loss is determined by the most limiting of three considerations: structural capability, prevention of flashing, and maintaining sufficient NPSH for the residual heat removal (RHR) pumps. These considerations are discussed as follows.

Structural Evaluation

Structural modifications to reinforce the limiting components (stiffening the end module cap and the anchoring of the end modules to carry the end thrust loads) have been completed on the Unit 1 strainer assemblies to accommodate an operating differential pressure of 10'. A similar modification is planned for Unit 2. Enclosure 3 provides excerpts from the revised structural analysis for the strainer modules demonstrating the acceptability of operating the Unit 1 strainers with differential pressure as high as 10'. Similar modifications to reinforce the Unit 2 strainer assemblies for this higher differential pressure are scheduled for installation during the fall 2009 refueling outage.

Enclosure 4 provides excerpts from the revised structural analysis of the connecting piping and supports for Unit 1 demonstrating acceptability of operation with a differential pressure as high as 10'. This revision was possible without modification of the installed piping and supports. A similar revision for the Unit 2 connecting piping and supports is in progress.

Flashing Evaluation

Enclosure 5 contains a calculation demonstrating that a debris loaded strainer assembly head loss of 10' does not cause flashing within the strainer assembly. The calculation considers flashing at the screens and at the strainer assembly outlet over a range of operating temperatures.

A unique containment isolation valve is located at the discharge of the sump strainer screen assembly. This valve presents a flow restriction that could also cause localized flashing if pressure at the screen outlet is too low. Therefore, Enclosure 5 also includes an evaluation to ensure that the pressure loss through the strainer assembly remains low enough to preclude flashing in these outlet valves. The calculation concludes that flashing will not occur anywhere in the strainer assemblies or in the sump outlet isolation valves with a total strainer head loss of 10'.

In reaching this conclusion, the calculation credits the pressure present in containment due to the sum of the partial pressures of air and water vapor (steam). The methodology used is consistent with Nuclear Energy Institute, NEI-04-07, Pressurized Water Reactor Sump Performance Evaluation Methodology, May 28, 2004, Volume II Attachment V-1 (ML041550279, ML041550332, ML041550359 and ML041550380). It does not rely on a transient analysis of the post-accident containment pressure and temperature. The text of the calculation contains the details of the derivation of the solution methodology.

NPSH Evaluation

The ECCS NPSH analyzed suction flow path begins at the outlet of the strainer assembly and assumes that the total pressure available at this point is equal only to that of the water vapor pressure (i.e., no submergence). Since the flashing evaluation demonstrates that the total pressure available at the outlet of the strainer assembly does not fall below the vapor pressure of the water, the ECCS NPSH evaluations are not affected by the maximum allowable strainer assembly head loss of 10' that may occur as the sump cools down.

Question 14

Please list the quantity and debris characteristics of the unqualified coating debris in containment.

NextEra Response

The quantity of unqualified coatings actually resident in the containments (including a 15% allowance applied to coatings outside of the zone of influence [ZOI] for future contingencies) has been calculated to be bounded as follows:

Coating Type	Volume	Density
Zinc coatings	1.95 ft^3	457 lb/ft^3
Alkyd coatings	6.83 ft^3	90 lb/ft^3
Degraded Epoxy coatings outside of the ZOI	13.16 ft^3	94 lb/ft^3
Unqualified Epoxy coatings	5.05 ft^3	94 lb/ft^3
Total Coatings Volume Outside ZOI:	26.99 ft^3	

Consistent with the approved guidance of NEI-04-07, it is assumed that all unqualified coatings fail to their constituent particle sizes as fine dust. Degraded epoxy coatings (abraded, delaminating, etc.) located outside of the zone of interest (ZOI) are assumed to fail as chips or flakes.

No limiting sources of aluminum coatings were identified. While there may be residual aluminum coating still present under the RMI on the reactor vessel, a break occurring adjacent to the reactor vessel would result in minimal fibrous debris. Therefore, the effects of chemical precipitants on screen performance due to a break in that location is bounded by the combined chemical and fiber effects of breaks occurring in the RCS loop compartments.

During a teleconference on June 22, 2009, the NRC Staff requested additional information which justifies why epoxy based coatings that were originally qualified, but have degraded and are outside the ZOI, are assumed to fail as chips or flakes.

Testing performed for Comanche Peak Steam Electric Station by Keeler & Long (ML070230390) has been reviewed and found to be applicable to the degraded DBA-qualified epoxy and inorganic zinc coatings applied at PBNP. In that test, epoxy topcoat / inorganic zinc primer coating system chips, taken from the Comanche Peak Unit 1 containment were subjected to DBA testing in accordance with ASTM D 3911-03, Standard Test Method for Evaluating Coatings Used in Light-Water Nuclear Power Plants at Simulated Design Basis Accident (DBA) Conditions. In addition to the standard test protocol contained in ASTM-D 3911-03, 10 μm filters were installed in the autoclave recirculation piping to capture small, transportable particulate coating debris generated during the test.

The test confirmed that while the inorganic zinc failed to powder form, the phenolic epoxy topcoat remained as relatively large (>1/32" diameter) pieces that were not transportable.

Question 15

The supplemental response indicated that the quantity of coatings debris from steel structures is represented by the surface area of a 10 diameter (D) "half sphere." This approach is not consistent the NRC safety evaluation (SE) dated December 6, 2004, on Nuclear Energy Institute (NEI) 04-07 "Pressurize Water Reactor Sump Performance Methodology," which calls for all of the coatings within a 10D ZOI of a pipe break to fail. Please provide the surface area of the coated steel structures in the 10D zone of influence (ZOI). Is this surface area bounded by the surface area of a 10D half sphere?

NextEra Response

The approach previously described was overly conservative and was inconsistent with the approved guidance of NEI 04-07. The calculation has been revised to more closely follow the guidance of NEI 04-07 in the subject of qualified coatings within the ZOI.

The revised calculation recognizes that a 10D ZOI would envelope a substantial portion of a reactor coolant system (RCS) loop compartment. To simplify the calculation, 100% of qualified steel coatings within the compartment are now assumed to fail. This amounts to 2,390 ft^2 of surface area, and contributes 2.28 ft^3 of epoxy coatings debris and 0.3 ft^3 of zinc coating debris.

This is a net reduction from the previously calculated volume of 4.53 ft^3 using the surface area of a half-sphere. Therefore, the surface area of the coated steel structures in the 10D ZOI was bounded by the surface area of the surface area of the half-sphere previously described.

Question 16

The supplemental response indicated that the quantity of coatings debris from concrete structures is represented by the surface area of a 4D "sphere." This approach is not consistent the NRC SE on NEI 04-07, which calls for the surface area of all coated concrete surfaces within a representative ZOI. Please provide the surface area of the coated concrete surfaces in a 4D ZOI around the limiting pipe break. Is this surface area bounded by the surface area of a 4D sphere?

NextEra Response

The previous approach, while conservative, was inconsistent with the approved guidance of NEI 04-07 and was overly conservative. The calculation has been revised to follow the guidance of NEI 04-07 in the subject of qualified coatings within the ZOI.

The revised calculation evaluated the maximum surface area of coated concrete surfaces within a 4D ZOI. The resulting area is 400 ft^2, contributing 1.3 ft^3 of epoxy coatings debris.

This is a net reduction from the previously calculated volume of 4.36 ft^3 using the surface area of a 4D sphere. Therefore, the surface area of the coated concrete structures in the 4D ZOI was bounded by the surface area of the surface area of the sphere previously described.

During a teleconference on June 22, 2009, the NRC Staff requested additional information relating to the basis of the 4D ZOI that was used for qualified coatings on concrete substrates.

To substantiate the reduction of the ZOI for qualified coatings to 4D, NextEra established the Level 1 concrete coatings inside postulated ZOIs, and procured reports of QA "JOGAR" testing of these coating systems on a concrete substrate.

The tests consisted of subjecting representative samples of the coatings to a freely expanding jet of water with stagnation conditions greater than or equal to 210 psig and 300°F. Utilizing the industry accepted high energy line break jet model set forth in ANSI/ANS-58.2-1988, Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture, it was determined that the piping length-to-diameter ratio (L/D) value associated with the bounding RCS cold leg break is less than 4.0. These stagnation conditions correspond to a coating damage pressure of approximately 52 psig.

The tested coating systems representative of the Level 1 coatings on concrete in the PBNP containments passed the test with no detectable damage, indicating that they have an effective ZOI of 4.0 or less.

Question 17

Considering your responses to the foregoing two RAIs, please provide the total quantities of qualified coatings in the respective ZOIs for concrete and steel surfaces, as well as the total quantities of degraded qualified coatings and unqualified coatings in containment. Are the quantities from your initial GL 2004-02 response (ML052500302) still accurate?

NextEra Response

The total quantities of the coatings were provided in the responses to Questions 14, 15 and 16 above. The quantities in the initial GL 2004-02 response are no longer correct. The reduced quantities stated above are being used.

Question 18

Please describe the debris characteristics and transport percentage (size, shape, density, and thickness) of the qualified, degraded qualified and unqualified coating debris.

NextEra Response

As stated in the response to Question 14, unqualified coatings and coatings within the ZOI are assumed to fail as fine particulates. Epoxy based coatings that were originally qualified, but have degraded (e.g. abraded or delaminating) and are outside the ZOI are assumed to fail as chips or flakes.

No attempts have been made to date to model transport of coatings debris by analysis. It is not planned that analysis will be performed because screen qualification testing has been used. In the tests, the quantity of coatings debris introduced into the test flume was scaled to the test screen surface area, modeling 100% of the coatings debris calculated for containment. The details of the surrogates used for coatings debris are provided in Performance Contracting Inc. letter to NRC, dated March 25, 2009, PCI-6016-02.01, Attachment 3, Sure-Flow® Suction Strainer – Testing Debris Preparation and Surrogates, SFSS-TD-2007, Revision 4 (Proprietary) (ADAMS Accession Number not available).

Question 19

Please provide the information requested under item (m) in the Revised Content Guide for GL 2004-02 Supplemental Response dated November 2007.

NextEra Response

Item (m) of Revised Content Guide for Generic Letter 2004-02, Supplemental Responses November 2007, dated November 11, 2007, (ML073110278) requests licensees to:

> *"...Provide the information requested in GL 04-02 Requested Information Item 2(d)(v) and 2(d)(vi) regarding blockage, plugging, and wear at restrictions and close tolerance locations in the ECCS and CSS downstream of the sump.*
>
> *GL 2004-02 Requested Information Item 2(d)(v)*
>
> *The basis for concluding that inadequate core or containment cooling would not result due to debris blockage at flow restrictions in the ECCS and CSS flow paths downstream of the sump screen, (e.g., a HPSI throttle valve, pump bearings and seals, fuel assembly inlet debris screen, or containment spray nozzles). The discussion should consider the adequacy of the sump screens mesh spacing and state the basis for concluding that adverse gaps or breaches are not present on the screen surface.*
>
> *GL 2004-02 Requested Information Item 2(d)(vi)*
>
> *Verification that the close-tolerance subcomponents in pumps, valves and other ECCS and CSS components are not susceptible to plugging or excessive wear due to extended post-accident operation with debris-laden fluids.*
>
> *If NRC approved methods were used (e.g., WCAP-16406-P with accompanying NRC SE), briefly summarize the application of the methods. Indicate where the approved methods were not used or exceptions were taken, and summarize the evaluation of those areas. Provide a summary and conclusions of downstream evaluations. Provide a summary of design or operational changes made as a result of downstream evaluations."*

GL 2004-02 Requested Information Item 2(d)(v)

Industry resolution and accepted test data for in-core/in-vessel effects are pending. As such, FPL Energy Point Beach is deferring a response to this aspect of Item 2(d)(v) pending NRC acceptance of a resolution approach.

A review of ex-vessel downstream components for potential flow restriction blockage was completed consistent with the NRC approved guidance of WCAP-16406-P, Revision 1. No deviations or exceptions were taken.

The ECCS sump screen perforation size is 0.066" diameter.

The limiting passageways in the ECCS and containment spray system (CSS) were reviewed, and the most limiting passageway was found to be larger than the largest assumed debris diameter. Therefore, blockage of the ECCS and CSS passageways due to debris laden fluid is not a concern.

The following paragraphs are excerpts from the evaluation:

> "…all piping diameters in the sump recirculation / injection flow paths are greater than 1.5 in. There are no globe valves in the ECCS and CSS lines. RHR heat exchanger outlet valves, 1&2-RH-624 & 625 are throttled to prevent RHR pump run out at certain conditions. These valves are 8 in butterfly valves …"

> "…the RHR heat exchanger… tube ID is 0.652 in… Since the RHR Heat Exchanger tube ID is greater than the largest assumed debris diameter … that could penetrate the containment sumps screens, tube plugging is not expected. Also, heat exchanger tube velocity is generally between 3-15 feet/sec … which is much greater than the sump velocity. Since the debris is assumed to penetrate the sump screens at a lower velocity, settling inside the heat exchanger tubes is not expected. Therefore, blockage inside PB-1 and PB-2 RHR heat exchanger tubing due to debris laden fluid is not a concern …"

> "The smallest ECCS and CSS process piping ID is 1.5"…which is larger than RHR heat exchanger tubing ID. This evaluation has determined that blockage due to debris laden fluid inside RHR heat exchanger tubing is not a concern. Therefore, since the ECCS and CSS process piping is larger than the RHR heat exchanger tubing, blockage of ECCS and CSS piping due to debris laden fluid is not a concern…"

> "Since [debris] terminal settling velocities are small by comparison to the process fluid velocities, introduction of debris into the instrument tubing is not expected. Therefore, blockage and abrasive wear associated with ECCS or CSS instrument tubing due to debris laden fluid are not expected."

> "Furthermore … all of PB-1 and PB-2 RG 1.97 commitment instruments tap into the process piping from the horizontal position to the upper half of the piping ... This excludes the possibility of debris settling in the subjected instrument tubing. Therefore, blockage and erosive wear to ECCS and CSS instrument tubing due to debris laden fluid are not expected …"

> "The most limiting orifice size in the ECCS and CSS…is 0.375" (CS Nozzles). Since 0.375" is larger than the maximum debris diameter of 0.0726", blockage is not expected …"

Technical Specification Surveillance Requirement (TS SR) 3.5.2.6 requires that every 18 months (refueling interval):

> "Verify, by visual inspection, each ECCS train containment sump suction inlet is not restricted by debris and the suction inlet debris screens show no evidence of structural distress or abnormal corrosion."

This provides assurance that the screens are free from adverse gaps or breaches.

<u>GL 2004-02 Requested Information Item 2(d)(vi)</u>

The evaluation of downstream effects was developed using a relatively large inventory of fibrous and particulate coatings debris, both of which either will be, or have been, reduced substantially (see the responses to Questions 9, 15 and 16). Therefore, the evaluation for excessive wear considered a substantially higher suspended debris concentration than is expected once all planned insulation replacements have been completed. As such, the following information derives from a conservative assessment.

An evaluation of ex-vessel downstream components was performed to verify that close-tolerance subcomponents are not susceptible to plugging or excessive wear due to extended post-accident operation with debris laden fluids. The evaluation was performed using the NRC-approved guidance of WCAP-16406-P, Revision 1, Evaluation of Downstream Sump Debris Effects in Support of GSI-191, dated October 27, 2005 (ML052500596). No deviations or exceptions were taken. The following paragraphs are excerpted from the evaluation.

> "Erosive wear in the ECCS and CSS components due to debris laden fluid has been analyzed. The PB-1 and PB-2 ECCS and CSS valves, heat exchanger tubing, instrument tubing, piping, and orifices were found to have adequate thickness such that erosive wear due to debris laden fluid will not compromise the design functions of these components for the required mission times."
>
> "The degradation of hydraulic performance for the designated mission times is acceptable based on the methodology provided in [WCAP-16406-P]. Therefore, the pump capabilities credited in the FSAR and license bases analysis to ensure that Peak (fuel) Cladding Temperature (PCT) limits are not exceeded during the time and flow critical transient portion of a design basis Loss of Coolant Accident (LOCA)."
>
> "The mechanical seal arrangement in the Point Beach RHR, CSS, and SI pumps are John Crane Type 1 and 1B mechanical seals. These seals are rugged in their construction and capable of operating at elevated temperatures. The arrangement of the spring/bellows mechanism will not be affected by the suspended solids used in this evaluation for the specified mission times. John Crane Type 1 and 1B seals have been successfully used in debris laden fluid such as pulp and paper, petrochemical, food processing, and waste water treatment. The design of the John Crane Type 1 and 1B mechanical seals uses a non-clogging single coil spring to supply the seal face closing force. Based on the design of the John Crane Mechanical Type 1 mechanical seal, a single point catastrophic seal failure due to the debris laden fluid used in this evaluation is not expected for the specified mission times."
>
> "According to the guidance provided in WCAP-16406-P, it is recommended that if the seal bushing in the mechanical seals are made of graphite or carbon then these seal bushings should be replaced with bronze or a similar material which is more wear resistant than the current graphite or carbon bushing. Since this evaluation is not taking credit for failure of the mechanical seals, it is not necessary to replace these seal bushings."
>
> "The drill-through diameters in the mechanical seal gland of the ECCS and CSS pumps are larger than the largest assumed debris size, 0.0726" that could penetrate the containment sump screens. Since there are no filters, cyclone separators, or other line obstructions present in the circuit, clogging of the mechanical seal flush/cooling lines is not expected."
>
> "Based on the above discussions, the RHR, CSS, and SI pump mechanical shaft seals are expected to perform satisfactory due to the debris laden fluid following the postulated LOCA for the designated mission times."
>
> "The RHR and CSS pumps of PBNP are single stage pumps and do not require pump vibration analysis."
>
> "The SI pumps at PBNP are multistage pumps and are evaluated for pump vibration. Since limited information exists from Point Beach and the SI pump manufacturer related to the SI pump rotor-dynamics, it is assumed that this information is not available. Therefore, the WCAP-16406-P wear model is used for the pump vibration evaluation."

"The wear rate model in [WCAP-16406-P] was used to assess the extent of wear on the wear components and its effect on SI pump vibration and hydraulic efficiency. It was determined that following a LOCA, debris induced wear on the pump wear components is not expected to exceed the design running clearance limit specified in Appendix R of WCAP-16406-P for the each of the wear components during the mission time of 30 days. Therefore, per [the WCAP-16406-P] criterion, the SI pump meets the requirements for vibration operability following a postulated LOCA and no further rotor-dynamic analysis is required."

No operational changes were made as a result of the downstream evaluations.

Question 21

The maximum aluminum concentration in the containment sump has been revised from a former calculation. The updated calculations show that less than 20 parts per million (ppm) will be the maximum aluminum concentration. Please provide the calculations used to determine final aluminum concentration, highlighting the differences in the revised calculations that show why a less than 20 ppm aluminum concentration is more representative of the post-LOCA sump environment. Please identify any important assumptions (e.g., pH) that significantly affect the calculation.

NextEra Response

The previous calculation was completed in April 2006; two months after the issuance of industry guidance contained in WCAP-16530, Evaluation of Post Accident Chemical Effects in Containment Sump Fluids to Support GSI-191, dated February 28, 2006, (ML060890509). In the absence of NRC guidance at the time, the calculation was performed using conservative assumptions and corrosion rates. While the information in WCAP-16530 was considered, most of the calculation development had occurred prior to issuance of WCAP-16530, and the results of the Integrated Chemical Effect Test (ICET) series of tests formed the basis of methodology and values used in the calculation.

During the development of this early calculation, it was believed that aluminum would remain substantially in solution at concentrations below approximately 50 ppm based on observations from ICET #4. PBNP uses a sodium hydroxide (NaOH) buffer, and had a considerable inventory of fiberglass insulation contributing silica to the sump pool chemistry. Therefore, the most similar test of the ICET series was #4. No significant precipitate formation had been reported in that test.

Subsequent developments, including both the NRC acceptance of the methodology in WCAP-16530 and industry guidance to assume that sodium aluminum silicate is completely insoluble at all concentrations, led FPL Energy Point Beach to create a new calculation (Enclosure 6). The new calculation implements the methodology of WCAP-16530 without exception or deviation.

The differences in inputs, assumptions and methodology between the two calculations are extensive and substantial, so a concise side-by-side comparison of the two calculations is not practical. The later calculation is not a revision or an update of the earlier calculation.

Since the April 2006 calculation did not implement an NRC-approved method of analysis, FPL Energy Point Beach no longer considers the results of the April 2006 calculation relevant to the resolution of GL 2004-02. Because that calculation is not valid, only the later calculation is provided in Enclosure 6.

The calculation contained in Enclosure 6 used the spreadsheet tool distributed with WCAP-16530 to determine the total quantity of sump chemical species. Multiple runs for various sets of postulated conditions were run to assess the sensitivity of the results to changes in parameters; however, some of the permutations represented non-credible accident sequences. The results of the multiple runs were then consolidated into summary tables for comparison and evaluation purposes.

Table 5-1 on Page 21 of Enclosure 6 is a matrix depicting the combinations of inputs used for each of the runs. Enclosure 6 is an abridgement of the calculation with most of the detailed spreadsheets and appended supporting material omitted for brevity. The detailed spreadsheets for the limiting design basis case (Table 7-1, Case 2.5) have been included.

The pH and temperature profiles used in the analyses are shown on Appendices A.6 through A.8 of Enclosure 6. The values for pH and temperature were all intentionally biased high to maximize corrosion rates and to conservatively bound the expected response.

Sump pH was maintained at a conservatively high 9.5 for each case. Similarly, the spray pH during the injection phase was held at a high of 10, while recirculation spray was held constant at a high of 9.5 (the same as the sump water). The timing of the transition from injection to recirculation was varied however, and found to be significant. Longer periods of spray injection with the higher pH spray resulted in a greater amount of corrosion from exposed metallic aluminum.

The other variables considered in establishing the chemical effects envelope (see Table 7-1, Page 29, Enclosure 6) were sump level (higher level results in a greater total quantity of chemical precipitate; whether corrosion inhibition is credited (it is not; but cases were run to determine the potential effect); whether pool volume is assumed to be mixed; and the debris mix. For the design bases cases, a worst case debris mix, that combined the largest quantities of insulation debris from all of the cases simultaneously, was used (Table 7-1, Cases 1.1 through 1.6, and Cases 2.1 through 2.6). Cases with debris mixes specific to the PBNP analyzed break results were also run to determine whether a significant reduction might be realized.

Table 6-1 on Page 24 of Enclosure 6 summarizes the most significant results. Cautions on usage of Table 6-1 are identified in the Design Review Comment Form located at the beginning of Enclosure 6. These cautions describe cases in Table 6-1 that are applicable design bases (Case 2.5 is the limiting credible case), cases that are not, and how to properly obtain the species concentrations using the information in the calculation. The concentrations listed in Table 6-1 were obtained using a different sump volume that is inconsistent with the derivation of the precipitate volumes and should not be used.

Question 22

Please provide a table that shows how the mass of precipitate formed varies as a function of sump pH and sump volume.

NextEra Response

The analysis used a constant pH profile that was intentionally biased high to conservatively bound accident conditions. As such, the analysis does not predict precipitate mass as a function of sump pH.

Table 7-1 of the calculation contains a summary of the results of the analysis runs. Cases 1.1 and 2.1 were the base cases and were performed with high sump levels and unmixed sumps. Cases 1.2 and 2.2 used the same inputs with the exception of low sump level. Therefore, comparison of these two pairs of cases provides a reasonable correlation between sump level and total precipitant formed.

PBNP Unit 1			PBNP Unit 2		
Case 1.1	Max sump volume	43,317 ft^3	Case 2.1	Max sump volume	43,317 ft^3
	Total Precipitant Mass	248.3 Kg		Total Precipitant Mass	274.8 Kg
Case 1.2	Min sump volume	22,995 ft^3	Case 2.2	Min sump volume	22,995 ft^3
	Total Precipitant Mass	169.7 Kg		Total Precipitant Mass	182.4 Kg

While these results demonstrate that a higher sump level results in a higher total quantity of precipitate, these results are not considered valid design inputs, because the use of the unmixed sump assumption is not realistic and is not valid.

During the preparation of the July 2009 response, it was discovered that the value for total precipitant mass reported for Case 1.1 in the April 2009 response was in error. It has been corrected in the above table.

Question 23

Please discuss why dissolution of concrete surfaces will not contribute significantly to the precipitate loading in the sump.

NextEra Response

Sodium hydroxide (NaOH) is used as a sump pH buffer at PBNP. This strong base favors the formation of sodium aluminum silicate. There is no significant source of phosphates as there would be if trisodium phosphate (TSP) was used as a buffer. Therefore, free calcium ions that may dissolve into solution will not precipitate out as calcium phosphate. This is demonstrated by the inputs (see Enclosure 6, Appendix A.1) where 10,000' of submerged exposed concrete were modeled) and the results of the chemical analyses (see Section 7 results for a discussion of the precipitant specie formed).

Question 24

Aluminum coatings are present on the reactor vessel as well as other components inside the containment. The supplemental response states that these coatings are formulated to withstand high temperatures and would therefore not be expected to fail during a LOCA. Operating experience at several US plants indicates that high-temperature aluminum coatings can disbond under normal operating conditions. These coatings are unqualified coatings and as such are expected to fail in pigment sized particles (including coatings outside of the ZOI). The aluminum would be separated, at least partially, from the silicone resin. These fine particles could then be readily exposed to either containment spray or sump fluid and would be available to contribute to chemical effects. For any aluminum coatings that are not covered with insulation materials that would remain intact and hold the coatings in place, please provide justification for not including the aluminum mass in the chemical effects evaluation.

NextEra Response

Research conducted in response to GL 2004-02 established that the coatings on the Unit 1 steam generators do not contain aluminum, and that the Unit 2 steam generators are not coated. The replacement insulation on the Unit 2 pressurizer (and that planned for the Unit 1 pressurizer) is not susceptible to removal based upon line break analyses.

Other smaller, line breaks in the vicinity of the pressurizer that may be close enough to remove some of the insulation and expose the underlying original aluminum based coating (e.g., a spray line or relief valve line break) are minimum and would not generate a substantial quantity of fibrous debris.

The remaining component within a loss-of-coolant (LOCA) ZOI that may have an aluminum pigmented coating is the reactor vessel. As discussed in the response to Question 1 above, the reactor vessel is insulated entirely with reflective metal insulation (RMI), and a break adjacent to the vessel would not result in a significant quantity of fibrous debris.

While the quantity of metallic aluminum that may be present in applied coatings was not explicitly accounted for in the chemical effects analysis, the following information shows that the effects are reasonably bounded by the analysis.

In the case of a break adjacent to the reactor vessel, it was postulated that all insulation on the vessel could be dislodged, and that any remaining aluminum coating on the vessel would be released to the containment sump. The PBNP reactor vessels can be approximated as right circular cylinders 33' tall and 12' in diameter. This provides a total surface area of approximately 1,470 ft^2, including both the upper and lower heads.

Heat resistant coatings are typically applied as very thin layers 0.001" to 0.002" thick. Conservatively assuming a layer 0.001" thick of solid metallic aluminum (no binder) gives a total volume of 211 in^3 (0.123 ft^3) of metallic aluminum. With a material density of 0.0975 lb/in^3 for aluminum, this represents a total quantity of 20.6 lbs (9.4 Kg) of aluminum.

A review of the spreadsheet for the most limiting design case for chemical effects (Enclosure 6, Table 7-1, Case 2.5) finds that 7.29 Kg of the aluminum that would be released to the sump is attributable to leaching from 1,276 ft^3 of fiberglass debris, and an additional 5.72 Kg attributable to leaching from 323 ft^3 of mineral wool. This is a total of 13 Kg of aluminum from fibrous insulation alone.

Since a break capable of exposing an aluminum coated surface would involve little, if any, fibrous insulation, the quantity of aluminum that would be released is bounded by the existing chemical effects analysis.

Question 25

Please provide an evaluation for the potential of deaeration of the sump fluid as it passes through the debris bed on the strainer. If deaeration can occur, please evaluate the effect that this can have on required net positive suction head on pumps taking suction from the sump as described in Reg Guide 1.82, Rev. 3, Appendix A.

NextEra Response

An analysis of the potential for deareation has been completed that uses the guidance contained in ISL-NSAD-TR-05-01, Development and Implementation of an Algorithm for Void Fraction Calculation in the '6224 Correlation' Software Package (V.V. Palazov, 01/2005).

The analysis determined that under the worst-case design basis head loss conditions for the screens (i.e. limited to 10' of head loss under cold conditions and with a minimum submergence of 2" at the top of the screens), the maximum gas fraction evolved would be 0.64%. This is considerably less than the conservative allowable limit of 2% previously established in station calculations for gas entrainment.

Under hot sump conditions, the void fraction is even lower at approximately 0.06%.

ENCLOSURE 2

NEXTERA ENERGY POINT BEACH, LLC
POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
GSI-191/GL 2004-02 (TAC NOS. MC4705/4706)
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

PERFORMANCE CONTRACTING, INC.,
CALCULATION TDI-6007-06, REVISION 5, JANUARY 8, 2009,
TOTAL HEAD LOSS - POINT BEACH NUCLEAR PLANT - UNIT 1 & 2

23 pages follow

PCI PERFORMANCE CONTRACTING INC

CALCULATION COVER SHEET

Calculation Number: **TDI-6007-06**

Technical Document Rev. No. **5** Addenda No.: **N/A**

Calculation Title: **Total Head Loss – Point Beach Nuclear Plant - Unit 1 & 2**

Safety Related? **YES**

Calculation Verification Method (Check One):

☒ Design Review ☐ Alternate Calculation ☐ Qualification Testing

Scope of Revision:

Specific Revision to address AREVA Large Flume testing results and addition of temperature range for reported values. Revision 5, Pages: All

Documentation of Reviews and Approvals:

Originated By: [redacted] Date 1/6/09

Verified By: [redacted] Date Jan. 6, 2009

Approved By: [redacted] Date 1/8/09

CALCULATION VERIFICATION CHECKLIST

Calculation Title: Total Head Loss – Point Beach Nuclear Plant - Unit 1 & 2

Revision: 5

	CHECKLIST	Yes	No	n/a
1.	Were inputs correctly selected and incorporated?	☒	☐	☐
2.	Are assumptions adequately described and reasonable?	☒	☐	☐
3.	Are the appropriate quality and quality assurance requirements specified?	☒	☐	☐
4.	Are the applicable codes, standards and regulatory requirements identified and met?	☒	☐	☐
5.	Have applicable construction and operating experience been considered?	☒	☐	☐
6.	Have the design interface requirements been satisfied?	☒	☐	☐
7.	Was an appropriate design method used?	☒	☐	☐
8.	Is the output reasonable compared to input?	☒	☐	☐
9.	Are specified parts, equipment, and processes suitable for the required application?	☐	☐	☒
10.	Are the specified materials compatible with design environmental conditions?	☐	☐	☒
11.	Have adequate maintenance features and requirements been specified?	☐	☐	☒
12.	Are accessibility and other design provision adequate?	☐	☐	☒
13.	Has adequate accessibility been provided to perform the in-service inspection?	☐	☐	☒
14.	Has the design properly considered radiation exposure?	☐	☐	☒
15.	Are the acceptance criteria incorporated in the design documents sufficient to allow verification?	☒	☐	☐
16.	Have adequate pre-operational and subsequent periodic test requirements been specified?	☐	☐	☒
17.	Are adequate handling storage, cleaning and shipping requirements specified?	☐	☐	☒
18.	Are adequate identification requirements specified?	☐	☐	☒
19.	Are requirements for record preparation, review, approval, retention, etc., adequately specified?	☐	☐	☒
20.	Has the appropriate Calculation Guideline Verification Checklist been reviewed and signed?	☒	☐	☐

Note: This is PCI form 3060-3 Revision 3

Verified by/Dat[redacted] **Initials:** [redacted]

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1.0 Purpose and Summary Results

The US Nuclear Regulatory Commission (USNRC) in generic safety issue (GSI) 191 identified it was possible that debris in PWR containments could be transported to the emergency core cooling system (ECCS) sump(s) following a main steam line break (MSLB) and/or a loss of coolant accident (LOCA). It was further determined that the transported debris could possibly clog the sump screens/strainers and impair the flow of water, thus directly affecting the resultant operability of the various ECCS pumps and the containment spray (CS) system pumps, and their ability to meet their design basis function(s). In order to address and resolve the various issues identified by the USNRC in GSI-191, utilities have implemented a program of replacing the existing ECCS sump screens or strainers with new and improved designs.

In order to address and resolve the specific issues associated with USNRC GSI-191 for the Point Beach Nuclear Plant – Unit 1 & 2 (PBNP-1/2) entered into a contract with Performance Contracting, Inc. (PCI). The primary objective of the contract was for PCI to provide a qualified Sure-Flow® Suction Strainer that has been specifically designed for PBNP-1/2 in order to address and resolve the NRC GSI-191 ECCS sump clogging issue.

PCI has prepared a Qualification Report specifically for the subject strainer. The Qualification Report is a compilation of the various documents and calculations that support the strainer qualification.

As part of the PBNP-1/2 Qualification Report, PCI has performed a number of hydraulic calculations in support of the replacement Sure-Flow® Suction Strainer. This calculation TDI-6007-06, *Total Head Loss – Point Beach Nuclear Plant – Unit 1 & 2* is one of a number of hydraulic calculations that specifically supports the design and qualification of the subject strainer.

This calculation addresses the total expected head losses across the suction strainer assembly that has been designed specifically for PBNP-1/2. This expected head loss is the combined total of the clean head loss associated with the strainer and attached piping, and the debris head loss. The clean head loss was determined in calculation TDI-6007-05, *Clean Head Loss – Point Beach Nuclear Plant – Unit 1 & 2*. The debris head loss is determined based on actual test results for a PBNP-1/2 strainer that has been specifically corrected for the PBNP-1/2 Specification design-basis post-LOCA water temperature. The tests were performed at the Alden Research Laboratory and independently verified by AREVA **[Reference 9.4]**. The calculations are only pertinent to PCI's Sure-Flow® Suction Strainer.

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The PBNP units each have two (2) separate recirculation strainer assemblies that individually and specifically feeds either the 'A' or 'B' train ECCS and CS system. Each horizontally oriented recirculation strainer assembly is comprised of fourteen (14) modules each made up of ten (10) strainer disks for a total strainer area of 1,904.6 ft^2, or a total of 3,809.2 ft^2 for each pair of strainers associated with one of the PBNP units. Flow leaves the strainers and enters a combination of pipe and fittings before discharging into the containment outlet. PCI drawings **[Drawings 10.1 - 10.11, inclusive]** provide details of the subject configuration.

Based on actual test results performed by PCI, it was determined that clean strainer head loss (CSHL) for the Sure-Flow® Suction Strainers is a function of two (2) independent variables: (1) strainer internal core tube diameter and (2) water flow rate exiting the strainer assembly. The quotient of these two independent variables, in turn, results in one independent variable, which is exit velocity (V_E).

The Clean Strainer Head Loss (CSHL) depends on the specific plant conditions for PBNP-1/2. The results of the Total Corrected Clean Strainer Head Loss (TCCSHL) calculation considering these conditions, including uncertainty, was calculated to be 0.560 feet of water. Full scale testing by AREVA at ARL found the actual CSHL to be 0.408 feet of water with the plenum head loss added.

The CSHL calculations account for the specific design of the PBNP-1/2 strainers. The debris laden head loss utilizes a series of tests conducted with a reduced scale strainer (with accompanying reduced surface area, reduced water flow rate, and reduced quantities of simulated post-LOCA debris). Each of the test parameters is reduced by the same fraction (i.e., a percentage of the full scale for each parameter). One parameter that is not changed is the approach velocity. It is kept the same as the full-scale design. The approach velocity is defined as the quotient of strainer flow rate and total surface area. The resultant value is 0.0026 ft/s, an extremely low approach velocity when compared to the design value for the original ECCS screens. The head loss across a particular debris bed is a function of two hydraulic variables: approach velocity and water dynamic viscosity. Accordingly, the strainer specific test results, utilizing accurately simulated post-LOCA debris and the design approach velocity, will be accurate for a given water dynamic viscosity, a parameter that is a function of water temperature. Therefore, the test results require correction for the viscosity at the specified post-LOCA water temperature, 212° F in the case of PBNP-1/2. The test results will then be representative of the full scale strainer under specified post-LOCA conditions.

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The results of the calculation are provided in **Table 1**. This calculation utilizes the results of clean strainer head loss testing previously conducted at the Fairbanks Morse Pump Company and the Electric Power Research Institute's (EPRI) Charlotte NDE Center for Prototypes I and II, respectively that is applicable to the current PCI Sure-Flow® Suction Strainer. It also utilizes the actual test results of the PBNP-2 strainer that were performed at the Alden Research Laboratory (ARL). The results of the subject two tests form the basis for calculating the PBNP-1/2 strainer total head loss.

Table 1 – Total Debris Laden Head Loss - Temperature Adjusted to Range 212 °F to 32 °F

Temperature °F	Head Loss ft
212 (Design Basis)	3.474
192	3.925
172	4.434
152	5.084
132	5.930
112	7.065
92	8.639
72	10.926
52	14.417
32	20.219

This calculation does not address the subjects of possible air ingestion, potential vortex, and void fraction issues as they relate to the PBNP-1/2 strainer. These topics will be specifically addressed in calculation TDI-6007-07, *Air Ingestion, Vortex & Void Fraction – Point Beach Nuclear Plant Unit 1 & 2.*

It was concluded that this calculation, an integral portion of the Qualification Report completely supports the qualification, installation, and use of the PCI Sure-Flow® Suction Strainer for Point Beach Nuclear Plant Unit 1 & 2 without any issues or reservations.

2.0 Definitions and Terminology

The following Definitions & Terminology are defined and described as they are utilized in this calculation.

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Sure-Flow® Suction Strainer – Strainer developed and designed by Performance Contracting, Inc. that employs Sure-Flow® technology to reduce inlet approach velocity.

Emergency Core Cooling System (ECCS) – The ECCS is a combination of pumps, piping, and heat exchangers that can be combined in various configurations to provide either safety injection or decay heat cooling to the reactor.

Point Beach Nuclear Plant Unit 1 & 2 – also known as Point Beach, PBNP-1/2, and PB-1/2.

AREVA NP, Inc. – also known as AREVA. AREVA is contracted by PCI to prepare and implement the Test Plan through Alden Research Laboratory. ARL will implement the testing under the AREVA quality program.

Alden Research Laboratory – also known as ARL. ARL is contracted by AREVA to perform the testing in their facility located at Holden, MA. The testing will be performed by ARL under the direction of PCI and AREVA.

Clean Strainer Head Loss (CSHL) – Is the calculated head loss for the Sure-Flow® Suction Strainer based on actual testing performed at the Electric Power Research Institute's (EPRI) Charlotte NDE Center, and Fairbanks Pump Company Hydraulic Laboratory. The later testing did not involve any debris.

Total Corrected Clean Strainer Head Loss (TCCSHL) – Is the total head loss associated with the complete Sure-Flow® Suction Strainer installation configuration for PBNP-1/2 (i.e., strainer and connecting piping and fittings) including uncertainty.

Total Debris Laden Head Loss (Temperature – Corrected - ARL Test Results) (TDLHL) – Is the TCCSHL added to the A-DLHL for the Sure-Flow® Suction Strainer based on the PBNP-1/2 testing that was performed at the Alden Research Laboratory (ARL). The PBNP-1/2 strainer testing performed at ARL is documented in **[Reference 9.4]**.

ARL Test Results - Debris Laden Head Loss – Temperature Corrected (A-DLHL) – Is the temperature corrected head loss for the PBNP-1/2 Sure-Flow® Suction Strainer based on the ARL test results utilizing the design basis debris loading **[Reference 9.4]**.

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3.0 Facts and Assumptions

The following Facts (designated as [F]) & Assumptions (designated as [A]) were utilized in the preparation of this calculation.

3.1 For the specified minimum post-LOCA water temperature of 212° F, the containment air pressure is 14.7 psia [F].

3.2 A flow velocity of 0.0026 fps would be characteristic of the PBNP-1/2 strainers, through a debris bed consisting of fibers and particulate is 100% viscous flow. Accordingly, the head loss is linearly proportional to dynamic viscosity [A].

3.3 A scale strainer, which is designed to maintain the same approach velocity as the full scale production strainer, can accurately simulate the performance of the full scale production strainer so long as the same scaling factor is used for strainer area, water flow rate, and debris quantities. The scaling factor is defined as ratio of the surface area of the scale strainer and the surface area of the full scale production strainer [A].

3.4 The head loss resulting from flow through a fiber – particulate debris bed at the approach velocity for the PBNP-1/2 strainer (0.0026 ft/s) **[Reference 9.3]**, is 100% viscous flow, as opposed to inertial flow. As viscous flow, head loss is linearly dependent on the product of viscosity and velocity. Therefore, to adjust the measured head loss across a debris bed with colder water, a ratio of water viscosities, between the warmer specified post-LOCA water temperature and the colder test temperature, can be multiplied by the measured head loss to obtain a prediction of the head loss with water at the specified post-LOCA temperature [A].

3.5 The total strainer head loss can be calculated by taking the sum of the calculated value of the Clean Strainer Head Loss **[Reference 9.3]** and the temperature adjusted, tested debris head loss [A].

3.6 The PCI Sure-Flow® Suction Strainer installations for PBNP-1/2 are the same. However, there are a number of differences with regard to the strainer discharge piping configuration for each of the four (4) strainer installations. Based on an assessment of each of the four (4) strainer discharge piping configurations, the piping configuration associated with PBNP-1 Strainer "B" would result in the greatest head loss due to this specific strainer configuration having the greatest equivalent pipe length (i.e., combination of straight pipe length and number and type of fittings). Accordingly, the PBNP-1 Strainer "B" piping configuration will be

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conservatively utilized as the basis for PBNP-1/2 to bound both units and all strainer discharge piping configurations with respect to strainer clean head loss [F & A].

3.7 Utilization of the PBNP-1/2 testing program performed at ARL and the subsequent test data and results **[Reference 9.4]** to support PBNP-1/2 calculations are based on the PBNP-1/2 Project specification **[Reference 9.1]** [F].

3.8 Any and all references to or discussion of the PBNP-1/2 strainer testing, test results, and similar related activities and discussions, actually means the PBNP-1/2 strainer testing at ARL and the subsequent test results **[Reference 9.4]** [F].

3.9 PCI has assumed that unknown piping, tubing, or openings added after the strainer installation are not directly connected to the PCI Sure-Flow® Strainer and are sealed (i.e., fluids and/or gases cannot enter and/or exit through the openings) [A].

3.10 The input data used in MS Excel spread sheets (if applicable) was verified by comparison to the design drawings and associated dimensions. The calculations resulting in output data are independently verified by hand calculation. Therefore, a MS Excel spread sheet is a convenience tool, but not relied upon as analytical software [F].

3.12 The Design Basis minimum specified post-LOCA water temperature is 212°F. The 212 °F temperature will be utilized to evaluate the total head loss. However, PBNP-1/2 has requested a series of head loss values for water with temperatures between 212 °F and 32°F, at 20 degree increments. The Total Debris Laden head loss will be determined at 212 °F and utilize the tested clean strainer head loss results to determine the final Total Debris Laden head loss. PCI will utilize a temperature correction correlation to obtain the subject head losses for the range between 212 °F and 32 °F temperatures [F].

3.13 Reynolds numbers are calculated in attachment A1 for temperatures between 32 °F and 212 °F using the flow and piping details from the CSHL calculation **[Reference 9.3]** and shown in Attachment 1, Table A1. [F].

4.0 Design Inputs

The following combination of PBNP-1/2 and PCI Design Inputs were utilized in the preparation of this calculation.

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4.1 Point Beach Nuclear Plant Specification, Specification No, PB-681, *Replacement of Containment Sump Screens,* Revision 1, August 25, 2005 **[Reference 9.1]**. This document provides design input associated with strainer flow rate, water temperature, and the maximum allowable head loss.

4.2 Performance Contracting, Inc. (PCI) Calculation TDI-6007-02, *SFS Surface Area, Flow and Volume Calculation,* Revision 1 **[Reference 9.12]**. This document provides relevant dimensions and other information specifically associated with the PBNP-1/2 strainers.

4.3 PCI Calculation TDI-6007-03, *Core Tube Design – Point Beach Nuclear Plant – 1/2,* Revision 0 **[Reference 9.2]**. This document provides relevant data with regard to flow rate in the PBNP-1/2 strainer.

4.4 PCI Calculation TDI-6007-5, *Clean Head Loss – Point Beach Nuclear Plant – 1/2,* Revision 4 **[Reference 9.3]**. This document provides the head loss associated with the "clean" PBNP-1/2 strainer and attached pipe and fittings.

4.5 AREVA Engineering Information Record, Document Identification No. 66-9093957-002, *Point Beach Test Report for ECCS Strainer Performance Testing* **[Reference 9.4]**. These documents provide the method and value of the tested debris head loss and the mechanism of adjusting the tested debris head Loss to the specified post-LOCA water temperature.

5.0 Methodology

PCI utilized two (2) distinct methodologies based on the entire strainer assembly configuration to determine the maximum thin bed head loss for this calculation: (1) calculate the Clean Head Loss for the PBNP-1/2 strainer **[Reference 9.3]** and (2) determine the peak design basis head loss based on reduced scale strainer testing utilizing the PBNP-1/2 specified design basis water temperature of 212° F **[Reference 9.1]** (adjust from the test water temperature to the specified water temperature) and the PBNP-1/2 specific debris mixture. The individual head loss results obtained are added together to obtain the total design basis head loss for the entire strainer assembly configuration.

The quantity of fiber and debris used in the scale strainer testing is based on the debris load stated in **[Reference 9.6]** with a 75% fiber reduction. PCI believes that the assumptions are conservative and are supported by the PBNP-1/2 test results at ARL **[Reference 9.4]**. Debris testing is then used to determine if the

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strainer is adequate to meet the specified design conditions. The actual scale strainer testing results are used as the basis for concluding that the strainer bounds the proposed size and design for the actual PBNP-1/2 strainer. PCI believes that the assumptions are conservative and are supported by the PBNP-1/2 strainer test results at ARL **[Reference 9.4]**.

6.0 Acceptance Criteria

PBNP-1/2 specified **[Reference 9.1]** that the total debris laden strainer head loss be calculated at a temperature of 212 °F in order to meet the required design basis NPSH requirements, and further specified **[Reference 9.7]** that a range of head loss values be determined between 212 °F and 32 °F at 20 degree increments. *The head loss values for the full range of temperatures will be presented in* **Table 8.**

The DLTHL-TC includes the strainer, strainer discharge, and addressing all possible debris loading combinations. This calculation addresses the possible debris loading combinations, and calculates the head loss associated with the strainer and the strainer discharge flow into the sump.

PCI has optimized its design of the Sure-Flow® Suction Strainers for PSL-2 to ensure preservation of head loss margin.

7.0 Calculation(s)

In order to determine the TDLHL, two (2) distinct calculation methodologies are employed as *described in section* ***5.0 Methodology****. One methodology* is utilized to separately calculate the head loss for the bare strainer, attached pipe and fittings, and the second methodology is used to determine the Total Debris Laden Head Loss – Temperature Corrected (TDLHL) design basis head loss based on PBNP-1/2 specific reduced scale strainer testing using a full sized representative strainer module with debris generation allocation mixture (A-DLHL).

NOTE: The PCI Sure-Flow® Suction Strainer installation for PBNP-1/2 is very similar in nature with only a slight difference with regard to the strainer discharge piping configuration. Accordingly, the discharge piping configuration differences are greater for PBNP-1, and its associated configuration will be utilized to bound both units with respect to strainer clean head loss.

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7.1 Clean Strainer Head Loss

As summarized in **Table 2** below, PCI calculated the clean strainer head loss (CSHL) for the PBNP-1/2 strainer in **[Reference 9.3]**. The total CSHL includes the expected head losses from the strainer (bare), attached strainer discharge piping and fittings connecting the strainer to the sump pit, and that associated with the water leaving the strainer discharge pipe as it enters the sump pit.

Table 2 - Total Corrected Clean Strainer Head Loss (TCCSHL) Results, ft	
TCCSHL @ 212 °F	**0.560**

The TCCSHL below includes a strainer only head loss calculated using the PCI regression formula as presented in **[Reference 9.4]**. The strainer regression formula value for head loss and its temperature corrected value for 212 °F are presented in **Table 3.** This value will be used later to determine the total debris laden head loss. Temperature correction is calculated using methodology provided in **Section 7.2.2.**

Table 3 - Clean Strainer Head Loss - Regression Formula, ft	
Strainer Head Loss (212 °F)	**0.1935**

7.2 Strainer Debris Laden Head Loss

The PBNP-1/2 strainer modules were sized based upon **[Reference 9.12]**. The amount of and the make-up of the debris that is specific to PBNP-1/2 was provided in **[Reference 9.6]**. The debris mixture specified in **[Reference 9.1]** was further analyzed by utilizing **[Reference 9.12]** to develop the actual debris mix (i.e., debris quantity and type) for the testing of the PBNP-1/2 specific strainer **[References 9.5]**.

The PBNP-1/2 Clean Strainer Head Loss tests performed at ARL are summarized in **Table 4.**

The CSHL based on the test result from ARL was temperature corrected to the PBNP design basis temperature (i.e., 212 °F). See **Section 7.2.2** for temperature correction methodology.

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Table 4 – ARL Tested Clean Strainer Head Loss			
Test Strainer Flow, gpm (Scaled)	**Ave. Temp. (°F)**	**Clean Strainer Head Loss, ft of water**	**Corrected Clean Strainer Head Loss, ft of water (212 °F)**
170.7	111.1	0.090	0.0417

The PBNP-1/2 Debris Laden Strainer Head Loss test is summarized in **Table 5.**

AREVA Test No. 6 **[Reference 9.4]** is the Design Basis test for PBNP-1/2. The PBNP-1/2 Design Basis test is intended to show recirculation at 2200 gpm with a water level above the top of the PBNP-1/2 strainer.

Additional information regarding both the Clean Head Loss and Debris Laden Head Loss testing that was performed at ARL is specifically discussed in detail in **[Reference 9.4]**.

Table 5 – ARL Tested Debris Laden Head Loss			
Test/Basis	**Strainer Debris Laden Head Loss**		
	Test Temp, °F	**HL - Ft of Water**	**HL corrected to 212 °F (Ft of Water)**
Test No. 6 - 170.42 gpm scaled flow	113.6	6.448	3.066

7.2.1 Temperature Correction Strainer Debris Laden Head Loss

The dynamic viscosity of the specific ARL test water temperatures and the PBNP-1/2 Design Basis temperature is taken from **[Reference 9.9]**. **Table 6** provides a summary of the dynamic viscosities associated with the various test and Design Basis water temperatures that are utilized in this calculation.

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The head loss for low velocity water in the laminar flow region through a debris bed of fibers plus particulate is linearly dependent on the water's dynamic viscosity. The PBNP Design Basis water temperature is 212 °F **[Reference 9.1]**. The debris head loss requires correction to this temperature to determine the head loss at the PBNP-1/2 Design Basis temperature of 212 °F. The strainer debris laden head loss for low velocity water flow through a debris bed of fibers plus particulate is linearly dependent on the water's dynamic viscosity **[Reference 9.10]**.

Table 6 – Water Dynamic Viscosity

Event	Temperature, °F	Dynamic Viscosity, lb/ft-s
PBNP-1/2 (ARL Testing) CSHL	111.1	4.083×10^{-4}
PBNP-1/2 (ARL Testing) DLHL	113.6	3.983×10^{-4}
PBNP-1/2 Design Basis Temperature	212	1.894×10^{-4}

7.2.2 Post-LOCA Temperature Correction Strainer Debris Laden Head Loss

A head loss correction, utilizing **Assumption 3.4**, which is based on the standard debris head loss equation **[Reference 9.11]** can be used to calculate a temperature adjusted debris head loss, HL_{TA}. The HL_{TA} adjusted temperature can be calculated by taking a ratio of dynamic viscosity values at the two different temperatures being considered (i.e., the test water temperature and the PBNP-1/2 specific post-LOCA sump water temperature).

Equation 1 $HL_{TA} = HL_{DL,C} (\mu_{ST} / \mu_{TT})$

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Where HL_{DLC} = Debris Loaded Head Loss, ft

μ_{ST} = dynamic viscosity at the post-LOCA specified temperature

μ_{TT} = dynamic viscosity at the average tested temperature

HL_{TA} = temperature adjusted debris head loss, ft

The HL_{TA}, as calculated above, is added to the clean strainer head loss that results in the DLTHL-TC for PBNP-1/2 based on the specified post-LOCA Design Basis temperature.

7.3 PBNP-1/2 Strainer Debris Laden Head Loss Summary

Table 7 summarizes the bounding values of head loss discussed above. All head losses are in feet of water. It was also conservatively assumed to add 6% for uncertainty and 10% for strainer discharge and collection head loss associated with the Clean Strainer Head Loss (CSHL) calculations to address any non-conservatism inherent in the use of standard head loss correlations **[Reference 9.3]**. The Clean Strainer Head Loss values are based on **[Reference 9.3]**, the tested strainer debris laden head loss is based on **Section 7.2**, and the temperature corrected debris laden head loss for post-LOCA conditions is based on **Section 7.2.2.**

PBNP-1/2 has requested a series of head loss values be calculated for water with temperatures between 32 °F and 212°F, at 20 degree increments. The Total Debris Laden head loss will be determined at 212 °F and utilize the tested clean strainer head loss results to determine the final Total Debris Laden head loss for this range of temperatures. PCI will use temperature correction correlation methodology presented in **Attachment 1** to calculate the subject head losses for the range between 32 °F and 212 °F temperatures. See **Table 8** for results of head losses calculated for the specified range.

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Table 7 – Total Debris Laden Head Loss

TCCSHL Ft. (Table 2)	Calculated CSHL, ft (Regression Formula) (Table 3)	Plenum Head loss (TCCSHL- CSHL)	ARL Tested CSHL ft. (Table 4)	A-DLHL ft. (Table 5)	TDLHL, ft of water at 212 °F (Plenum Head Loss + ARL CSHL+ A-DLHL)
0.560	0.1935	0.3665	0.0417	3.066	3.474

Table 8 – Total Debris Laden Head Loss - Temperature Adjusted to Range 212 °F to 32 °F

Temperature °F	CSHL (ft)	Piping Head Loss (ft)	Debris Head Loss (ft)	Total Corrected Head Loss (ft)
212	0.0417	0.3665	3.066	3.474
192	0.0468	0.4123	3.465	3.925
172	0.0531	0.4154	3.966	4.434
152	0.0613	0.4184	4.604	5.084
132	0.0719	0.4215	5.436	5.930
112	0.0862	0.4276	6.551	7.065
92	0.1061	0.4367	8.096	8.639
72	0.1350	0.4581	10.333	10.926
52	0.1796	0.4673	13.770	14.417
32	0.2539	0.4887	19.476	20.219

Originated By: [redacted]

Date 1/6/09

7.4 Debris Bypass

As part of the PBNP-1/2 strainer testing plan, water samples of the debris mixture (i.e., debris type and quantity) were taken of the strainer discharge water, immediately adjacent to the subject strainer. This was done in order to determine the size, quantity and weight of the various debris mixture components (i.e., fibers and suspended particulate) that were being transported through the strainer during the test. Analysis of the debris bypass data is not part of the scope of this technical document. The debris bypass analysis results can be found in the AREVA Test Report **[Reference 9.4]**.

8.0 Conclusions

This calculation and supporting portions thereof, considered all of the previous testing that has been performed for the various PCI Sure-Flow® Suction Strainer, including uncertainty. The temperature corrected head loss associated with the debris only on the strainer is **3.066 feet of water** at 212 °F. The predicted result for total debris laden head loss, the sum of the calculated clean strainer head loss including uncertainties and the strainer debris laden head loss is **3.474 feet of water** at 212 °F.

It was concluded that this specific calculation completely supports the qualification, installation, and use of the PCI Sure-Flow® Suction Strainer for Point Beach Nuclear Plant – Unit 1 & 2 without any issues or reservations.

Originated By: [redacted] Date 1/6/05

9.0 References

9.1 Point Beach Nuclear Plant, Point Beach Nuclear Plant Specification, *Replacement of Containment Sump Screens*, Specification No. PB-681, Revision 2

9.2 Performance Contracting, Inc. (PCI) Calculation TDI-6007-03, *Internal Core Tube Slot Design for PBNPs Suction Strainers*, Revision 0

9.3 Performance Contracting, Inc. (PCI) Calculation TDI-6007-05, *Clean Head Loss – Point Beach Nuclear Plant – Unit -1/2*, Revision 4

9.4 AREVA Engineering Information Record, Document Identification No. 66-9093957-002, *Point Beach Test Report for ECCS Strainer Performance Testing,*

9.5 AREVA NP Engineering Information Record, Document Identification No. 51-9021513-000, *Point Beach Units 1 & 2 ECCS Strainer Performance Test Plan*, Revision 0

9.6 PBNP Letter No. NPL 2008-0162, Design Information Transmittal (DIT) in Support of Sump Strainer Qualification Testing the week of July 14, 2008, July 9, 2008

9.7 PBNP Letter No. NPL 2008-0264, Design Information Transmittal (DIT) in Support of PCI Calculation TDI-6007-06 Rev. 5, October 5, 2008

9.8 Crane Technical Paper No. 410, *Flow of Fluids through Valves, Fittings, and Pipe*, 1988

9.9 Spirax Sarco USA Webpage (http://www.spiraxsarco.com/us/resources)

9.10 USNRC NUREG/CR-6224 "Correlation", publicly available software

9.11 NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology", Rev. 0, December, 2004

9.12 Performance Contracting, Inc. (PCI) Calculation, TDI-6007-02, *SFS Surface Area, Flow and Volume Calculation*, Revision 2

9.13 Fluid Mechanics With Engineering Applications, Robert L. Daugherty and Joseph B. Franzini, Seventh Edition, 1977, McGraw-Hill Bookl Company, Inc.

Originated By: [redacted] Date 1/6/09

10.0 Drawings

10.1 SFS-PB1-GA-00, Revision 9, Point Beach Unit 1, Sure-Flow® *Strainer, Recirc Sump System*

10.2 SFS-PB1-GA-02, Revision 9, Point Beach Unit 1, Sure-Flow® *Strainer, B Strainer*

10.3 SFS-PB1-GA-03, Revision 9, Point Beach Unit 1, Sure-Flow® *Strainer, A Strainer*

10.4 SFS-PB1-GA-04, Revision 6, Point Beach Unit 1, Sure-Flow® *Strainer, Piping B Layout*

10.5 SFS-PB1-GA-05, Revision 9, Point Beach Unit 1, Sure-Flow® *Strainer, Piping A Layout*

10.6 SFS-PB1-PA-7100, Revision 4, Point Beach Unit 1, Sure-Flow® *Strainer, Module Assembly*

10.7 SFS-PB2-GA-00, Revision 3, Point Beach Unit 2, Sure-Flow® *Strainer, Recirc Sump System Layout*

10.8 SFS-PB2-GA-02, Revision 9, Point Beach Unit 1, Sure-Flow® *Strainer, A Strainer*

10.9 SFS-PB2-GA-03, Revision 9, Point Beach Unit 1, Sure-Flow® *Strainer, B Strainer*

10.10 SFS-PB2-GA-04, Revision 5, Point Beach Unit 2, Sure-Flow® *Strainer, Piping Assembly Layout*

10.11 SFS-PB2-PA-7100, Revision 3, Point Beach Unit 2, Sure-Flow® *Strainer, Module Assembly*

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Attachment 1

Point Beach Debris Laden Head Loss Temperature Corrected Values

Per Section 7.3, PBNP requested that total debris laden head losses be calculated for a range of temperatures. The total debris laden head loss is calculated by adding the ARL test CSHL, the ARL test debris laden head loss, and the piping head loss calculated in the CSHL calculation **[Reference 9.3]**. This calculation has already provided these values at a design temperature of 212 °F. To calculate the head losses for the PBNP specified range of temperatures, PCI will use the following methodology:

A. The CSHL value is calculated **[Reference 9.3]** using the PCI derived regression equation. The equation uses kinematic viscosity to address the various temperatures. The CSHL value used in this calculation is based on the results of the CSHL testing performed at the ARL test facility. Temperature adjustment of the range of PBNP requested temperatures will be performed utilizing the kinematic viscosity, as addressed in the PCI regression equation. The CSHL value calculated at 212 °F will be adjusted for the range of temperature values utilizing kinematic viscosity as follows:

Equation 1 $HL_{CS,TA} = HL_{CS} (\nu_{AT} / \nu_{DT})$

Where ~~HL_{CS} = As Tested Clean Strainer Head Loss, ft~~

ν_{DT} = Kinematic viscosity at the post-LOCA design temperature (212 °F)

ν_{AT} = Kinematic viscosity at the post-LOCA adjusted temperature (i.e.; 32 °F to 190 °F)

$HL_{CS,TA}$ = temperature adjusted debris head loss, ft

Kinematic viscosity values were calculated using the following equation;

Equation 2 $\nu = \mu / \rho$

Where μ = dynamic viscosity (lb/ft-s)
ρ = density (lb/ft^3)
ν = kinematic viscosity (ft^2/s)

The dynamic viscosity and density values were taken from **[Reference 9.9]** for values above 32 °F. Dynamic viscosity and density values for 32 °F were taken

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from **[Reference 9.13]**. The values of kinematic viscosity, dynamic viscosity and density are listed in **Table A-1**.

B. The piping head loss is calculated using the following equation:

Equation 3 $HL_{pipe} = f\ L/D\ V^2/2g$

The specified temperature range requires determining friction factors for the temperature range. A Reynolds number is required to be calculated for the flow conditions in order to determine the friction factor used in the piping head loss equation. The friction factor can be taken from tables on page A-25 in Crane **[Reference 9.8]** after calculating the Reynolds number. Reynolds numbers are calculated using the following equation;

Equation 4 $Re = V\ D\ /\ \nu$

The piping head loss is calculated in the CSHL calculation **[Reference 9.3]** using values for 16 inch piping having a fluid velocity, V = 3.683 ft/s and a piping diameter, D = 1.302 ft. Values for kinematic viscosity, ν for the temperature range were taken from **[Reference 9.9 and 9.13]** and are included in **Table A1.** Values for Reynolds number were calculated for the temperature range, and the friction factor was read from the Crane table and input into **Table A-1**.

From the HL equation above, the terms $L/D\ V^2/2g$ are assumed to be constant for this temperature adjustment. From **Table 7** in section 7.3 of this calculation, the piping head loss total at 212 °F is 0.3665 ft. The friction factor, f, for 212 °F is 0.012. Knowing the head loss and the friction factor, the constant term can be calculated as:

HL	= f x constant
0.3665	= 0.012 x constant
Constant	= 30.542

This constant term, along with the friction factors from Crane will be used in the **HL_{pipe}** equation to calculate the various piping head losses within the temperature range specified in **Table A-1**.

C. The debris laden head loss also requires temperature adjustment. As stated in section 7.3 of this calculation, debris head loss can be temperature adjusted using the following methodology;

Equation 5 $HL_{DL,TA} = HL_{DL}\ (\mu_{AT}\ /\ \mu_{DT})$

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Where HL_{DL} = Debris Loaded Head Loss, ft

μ_{AT} = dynamic viscosity at the post-LOCA adjusted temperature

μ_{DT} = dynamic viscosity at the post-LOCA design temperature

$HL_{DL,TA}$ = temperature adjusted debris head loss, ft

The temperature adjusted CSHL from A is added to the temperature adjusted piping head loss from B and the temperature adjusted debris laden head loss, from C above, to calculate the DLTHL-TC for PBNP-1/2 based on the specified post-LOCA Design Basis temperatures.

Table A-1 provides a summary of the final DLTHL-TC values as well as the various reference design inputs.

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Table A-1 – Total Debris Laden Head Loss – Temperature Adjusted										
°F	Dynamic Viscosity μ (lb/ft-s)	Density ρ (lb/ft³)	Kinematic Viscosity ν (ft²/s) (ν=μ/ρ)	Reynolds No. Re (VD/ν)	Friction Factor, f (Crane page A25, 16 inch pipe)	ARL CSHL (ft) at 212 °F – temp adjusted using ν factor	Piping Head Loss (ft) - calculated using temp adjusted f value	ARL Debris Head Loss (ft) - Adjusted using μ factor	Total Corrected Head Loss (ft)
212	1.8938E-04	59.83	3.1653E-06	1614944.20	0.012	0.0417	0.3665	3.066	3.474
192	2.1406E-04	60.31	3.5492E-06	1351076.06	0.0135	0.0468	0.4123	3.465	3.925
172	2.4496E-04	60.75	4.0320E-06	1189290.10	0.0136	0.0531	0.4154	3.968	4.434
152	2.8439E-04	61.16	4.6501E-06	1031208.72	0.0137	0.0613	0.4184	4.604	5.084
132	3.3580E-04	61.52	5.4586E-06	878478.07	0.0138	0.0719	0.4215	5.436	5.930
112	4.0467E-04	61.83	6.5447E-06	732693.36	0.014	0.0862	0.4276	6.551	7.065
92	5.0009E-04	62.09	8.0542E-06	595377.83	0.0143	0.1061	0.4367	8.096	8.639
72	6.3827E-04	62.29	1.0247E-05	467961.13	0.015	0.1350	0.4581	10.333	10.926
52	8.5055E-04	62.41	1.3630E-05	351829.38	0.0153	0.1796	0.4673	13.770	14.417
32	0.001203	62.42	1.92722E-05	248818.10	0.016	0.2539	0.4887	19.476	20.219

Originated By: [redacted]

Date 1/6/09

ENCLOSURE 3

NEXTERA ENERGY POINT BEACH, LLC
POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
GSI-191/GL 2004-02 (TAC NOS. MC4705/4706)
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

PERFORMANCE CONTRACTING, INC.
CALCULATION PCI-5344-S04, SEPTEMBER 25, 2008
STRUCTURAL EVALUATION OF
CONTAINMENT EMERGENCY SUMP STRAINERS (ABRIDGED)
POINT BEACH NUCLEAR PLANT, UNITS 1 & 2

30 pages follow

Automated Engineering Services Corp.	Calculation Package	Page 1	of 182

Calculation Number: PCI-5344-S04	
Calculation Title: Structural Evaluation of Containment Emergency Sump Strainers	
Client: Performance Contracting Inc.	**Station:** Point Beach
Project Number: PCI-5344	**Unit(s):** 1 & 2
Project Title: Point Beach Strainer Qualification	

Safety Related Yes ☒ No ☐

Revision	Affected Pages	Revision Description	Approval Signature / Date	Signature / Initials of Preparers & Reviewers
0	All	Initial Issue.	[redacted] 9/25/2008	**Prepared by:** [redacted] **Reviewed by:** [redacted]

REVIEWER'S CHECKLIST FOR DESIGN CALCULATIONS SHEET 1 of 2

STATION: Point Beach NUCLEAR SAFETY RELATED: YES ☒ NO ☐

PROJECT NO: PCI-5344 CLIENT: Performance Contracting Inc.

CALCULATION TITLE: Structural Evaluation of Containment Emergency Sump Strainers

CALC. NO: PCI-5344-S04 CALC. REV. NO: 0

INDICATE THE DESIGN INPUT DOCUMENTS USED:

TYPE OF DOCUMENT	DOCUMENT ID, REV AND/OR DATE	YES	N/A	COMMENT
1. General Design Basis	3, 5, 9, 13, 22, 23, 27, 31, 46	X		
2. System Description			X	
3. Design information package from related equipment vendor	10, 18, 24, 28, 29, 34, 35, 48, 51	X		
4. Electrical Discipline Input			X	
5. Mechanical Discipline Input			X	
6. Control Systems Discipline Input			X	
7. Structural Discipline Input	4, 7, 12, 16, 17, 19, 20, 26, 30, 32, 33, 34, 35, 38,39, 44, 47	X		
8. Specifications	1, 2	X		
9. Vendor Drawings	6, 36, 37, 40, 41, 42, 43, 45, 50	X		
10. Design Standards			X	
11. Client Standards	11, 14, 15	X		
12. Checked Calculations	8, 24, 27, 28	X		
13. Other (specify)	21,25 (AES QA Files)	X		

PREPARER'S SIGNATURE: [redacted] DATE: 09/25/2008

REVIEWER'S SIGNATURE: [redacted] DATE: 09/25/2008

APPROVER'S SIGNATURE: [redacted] DATE: 09/25/2008

REVIEWER'S CHECKLIST FOR DESIGN CALCULATIONS — SHEET 2 of 2

PROJECT NO: PCI-5344

CALC. NO: PCI-5344-S04, Revision 0

REVIEWER TO COMPLETE THE FOLLOWING ITEMS:	YES	NO	N/A	COMMENT
1. Has the purpose of the calculation been clearly stated?	X			
2.. Have the applicable codes, standards and regulatory requirements been:				
A. Properly Identified?	X			
B. Properly Applied?	X			
3. Were the inputs correctly selected and used?	X			
4. A. Was Design Input Log used?		X		
B. If 4A is No, provide Manager's signature in Comment column to signify approval of Design Input Documents used in the calculation.				[redacted]
5. Are necessary assumptions adequately stated?	X			
6. Are the assumptions reasonable?	X			
7. Was the calculation methodology appropriate?	X			
8. Are symbols and abbreviations adequately identified?	X			
9. Are the calculations:				
A. Neat?	X			
B. Legible?	X			
C. Easy to follow?	X			
D. Presented in logical order?	X			
E. Prepared in proper format?	X			
10. Is the output reasonable compared to the inputs?	X			
11. If a computer program was used:				
A. Is the program listed on the ASL and has the SRN been reviewed for any program use limitations?	X			
B. Have existing user notices and/or error reports for the production version been reviewed as appropriate?	X			
C. Were codes properly verified?	X			
D. Were they appropriate for the application?	X			
E. Were they correctly used:	X			
F. Was data input correct?	X			
G. Is the computer program and revision identified?	X			

TABLE OF CONTENTS

1.0 PURPOSE/OBJECTIVE

The purpose of this calculation is to qualify the Performance Contracting Inc. (PCI) Suction Strainers to be installed in Florida Power and Light's Point Beach Nuclear Plant, Units 1 and 2. This calculation evaluates, by analysis, the strainer modules as well as the supporting structures associated with the new strainers.

2.0 METHODOLOGY

The evaluations are performed using a combination of manual calculations and finite element analyses using the GTSTRUDL Computer Program, (Reference [21]), and the ANSYS Computer Program (Reference [25]). The evaluations follow the requirements of the Strainer Design Specification PB-681 (Reference [1]). Exceptions from these requirement, when taken, are discussed and justified within this calculation.

Seismic Loads

The strainer is categorized as Seismic Class I equipment and is required to be operable during and after a safe shutdown earthquake (SSE) without exceeding normal allowable stresses as specified in Section 5.4.7 of DG-C03 Seismic Design Criteria Guideline (Reference [15]). Strainer Design Specification PB-681 (Reference [1]), requires the strainer to be evaluated for two operating conditions. The first condition is a "dry" condition with no recirculation water inside or external water present. The second condition is a submerged "wet" condition with recirculation water. For the seismic evaluation the strainer will be considered submerged and full of water. The water level is considered to be a minimum of 10' above the 8' floor elevation (El. 11'- 2") per Reference [46]. The piping "dry" state with its associated mass being much less, will not be considered as it is less severe than the "wet" state.

Per the specification, the seismic evaluation is required to take into account any seismic slosh (analyzed at the seismic worst-case water level) of the recirculation water. Based on Reference [8], because of the negligible load magnitudes, it is determined that the seismic slosh loads in PWR containments are insignificant by comparison with other seismic loads. Therefore, seismic slosh loads are neglected from the analysis (refer to Section 6.2.3 for further explanation). Note that the sloshing calculation of Reference [8] is done for the Prairie Island strainer project and it is representative for all PWR containments in general, and therefore, it is applicable for use in this calculation. The "wet" strainer operating condition considers the strainer assemblies submerged in still water at the seismic worst-case water level when subjected to seismic inertial loads. The inertial effects of the added hydrodynamic mass due to the submergence of the strainer is considered.

The strainer is seismically qualified using the response spectra method. The applicable seismic spectra are provided in Seismic Qualification Specification Sheet SQ-002243 (Reference [2]). These loads are applied to the strainer through base motion response spectra as detailed in the Seismic Design Criteria Guideline DG-C03 (Reference [15]).

The strainer is located on the 8' floor elevation of the containment. The response spectrum chosen is for the 6.5' elevation of the containment. The containment liner plate is located at the 6.5' elevation and there is an additional 1.5' of concrete on top of the liner plate. The slab between the 6.5' elevation and the 8' elevation is very rigid. Thus it is appropriate to use the response spectrum for the 6.5' elevation. The vertical direction response spectrum is 2/3 the value of the maximum ground horizontal response spectra.

The strainer is excited in each of the three mutually perpendicular directions, two horizontal and one vertical. Per Reference [11], the modal combination is performed by the use of the double sum method to account for the effects of modal coupling in the response (i.e. closely spaced modes). An earthquake duration of 30.24 seconds was used in the analysis per DG-C03, Appendix C. Appendix N of the ASME code indicates that the maximum accelerations generally occur in the first 10 seconds. Two analysis were run - one with 10 sec and one with 30.24 sec. Since the results were the same, the analysis with 30.24 seconds is the official documented seismic analysis. Responses from the vertical and one horizontal direction (worst case direction) are applied simultaneously and combined by absolute summation (Reference [15], paragraph 5.4.4.b). The cutoff frequency is taken at 30 Hz or a minimum of 5 modes are included. Zero Period Acceleration (ZPA) residual mass effects will be considered. The ZPA response will be added to the response spectra loads by SRSS.

The strainer is considered as a "bolted steel frames" structure and the damping values for seismic loads are taken as 2% for the Operating Basis Earthquake (OBE) and 5% for the Safe Shutdown Earthquake (SSE) as required by Seismic Design Guide DG-C03 (Reference [15]).

Operating Loads

Operating loads are comprised of weight and pressure loads. The weight of the strainer includes the weight of the strainer self weight and the weight of the debris, which accumulates on the strainer. The debris weight is taken from Reference [27].

The pressure load acting on the strainer is the differential pressure across the strainer perforated plates in the operating condition. Conservatively, this is taken as the hydrostatic pressure associated with the maximum allowed head loss through the debris covered strainers. This is defined as a minimum of 10 feet of water in DIT-008 (Reference [46]).

There are no thermal expansion loads since the strainers are basically free to expand without restraint. Note that the piping is not rigidly attached to the strainer modules, therefore the piping is also free to expand without imposing any thermal loads on the strainers. The design temperature is taken equal to the maximum operational inlet temperature to the RH Exchangers of 250 °F (Reference [1]).

Software

MathCad software is used to generate the calculations. All MathCad calculations are independently verified for accuracy and correctness as if they were manually generated. ANSYS is used for the analysis of the inner gap plate. ANSYS Version 5.7.1 is fully verified with no restrictions or limitations. GTSTRUDL Version 25 is used in the seismic response spectra analysis of the strainer modules. GTSTRUDL Version 25.0 is verified and validated under the AES QA program as documents in the AES validation and maintenance file (Reference [21]). The validation of GTSTRUDL was a partial validation and only validated certain commands. These commands are listed in the validation report. The GTSTRUDL runs utilized several commands outside the scope of this validation. A list of these commands, and their alternate validation method used for this particular application, is provided below:

Command	Validation Method
GENERATE REPEAT	The GENERATE and REPEAT commands are used to automatically generate member nodes and incidences. These generated items for these models are verified manually.

Command	Validation Method
JOINT TIES SLAVE RELEASES	The JOINT TIES and SLAVE RELEASES commands are used in conjunction with MEMBER TEMPERATURE LOADS to account for the preload on the connecting rods. The commands also constrain the pipe spacers and connecting rods to move together in certain degrees of freedom. Their use is acceptable because the nodal displacements are manually compared for these nodes to confirm the command is working as planned.
MEMBER TEMPERATURE LOADS	This command applies a specified temperature increase/decrease to a given member. This command is used as a simple way to generate preload in the rods. Its use is acceptable because the preloads produced by this load are verified manually.
DEFINE GROUP	This command groups members and/or joints together for easier specification of member properties and load placements. This command is verified by checking manually that the cross sections and loads are applied properly to each member.
MEMBER ADDED INERTIA	This command was used to apply the water weight of the system directly on to members that would carry that water for a certain direction of motion. This command was verified manually by listing the dynamic mass summary and comparing the total dynamic mass in each direction to the calculated masses.

PIPE	PIPE is a command used to specify the cross section of the core tube. It is necessary to use this command rather than referencing a pipe cross section from a table because the diameter and thickness are unique to the strainer and are not available in the provided tables. Because GTSTRUDL uses only the section properties when code checking, the properties are printed out for selected members defined by this command and those properties are verified manually.
TABLE 'RBARS' TABLE 'BARS' TABLE 'ROUND' TABLE 'MYCHAN'	'RBARS', 'BARS', 'ROUND', and 'MYCHAN' are predefined GTSTRUDL tables that contain steel cross sections for rectangular, round (for both 'BARS' and 'ROUND'), and channel shapes. The members that are defined by these tables are subjected to loadings and then code checked in GTSTRUDL. These tables are verified in the same fashion as for the PIPE command listed above. In addition any code checks performed by GTSTRUDL for these sections are manually verified.

The limitations and program error reports for GTSTRUDL Version 25 (Reference [21]) were reviewed for applicability to the GTSTRUDL runs made for this calculation. The limitations for the ASD9 Code check were found not to be applicable for this calculation (none of the components are subjected to significant torsion, therefore warping torsion stresses would be negligible). Also, steel cross sections that were not available in the GTSTRUDL cross section libraries had to be created for the face disk edge channels, the external radial stiffeners, the debris stops, the seismic stiffeners, the ends of the connecting rods to account for the threading, and the ends of the external radial stiffeners where they are welded to the seismic stiffeners. These cross sections were verified by outputting the computed properties of the cross sections and checking these values manually. All known issues, including Part 21 notifications, have been reviewed for applicability in accordance with the AES QA program. Work arounds to existing issues or errors have been utilized as required.

3.0 ACCEPTANCE CRITERIA

The strainer components shall meet the requirements of the strainer design specification PB-681 (Reference [1]). As stated in PB-681, the detailed evaluations are to be performed using the rules, as applicable, of ANSI/ASME B31.1 Power Piping 1998 Edition through 1999 Addenda (Reference [5]).

The strainers are classified as "other pressure-retaining components" as described in Paragraph 104.7 of the B31.1 Code (Reference [5]). Under Paragraph 104.7.2, the code allows "The pressure design of components not covered by the standards listed in Table 126.1 or for which design formulas and procedures are not given in this Code shall be based on calculation consistent with the design criteria of this Code. These calculations shall be substantiated by one or more of the means stated in (A), (B), (C), and (D) below. Based on this paragraph, since the B31.1 Code does not provide specific design rules for a pressure retaining component such as a strainer, design guidance will be taken from the ASME Boiler and Pressure Vessel Code (Reference [3]).

The ASME Code is consistent with the B31.1 Code and is a logical alternative to B31.1 rules. The substantiation method described in Paragraph 104.7 of the B31.1 Code is Alternative D, which allows for "detailed stress analysis, such as the finite element method, in accordance with the ASME Boiler and Pressure Vessel Code, Division 2, Appendix 4, except that the basic material allowable stress from the Allowable Stress Tables of Appendix A shall be used in place of S_m." Section III, Subsection NC of the ASME Code will be used as this presents the most general criteria for the design of pressure retaining components.

The use of the ASME Code is primarily for the qualification of pressure retaining parts of the strainer which are not covered in B31.1 (perforated plate, and internal wire stiffeners). Some parts of the strainers (radial stiffeners, connecting rods, edge channels, seismic stiffeners, etc.) are classified as part of the support structure. These types of components are covered under the AISC Code (Reference [9]). Additional guidance is also taken from other codes and standards where the AISC does not provide specific rules for certain aspects of the design. For instance, the strainers are made from stainless steel materials. The AISC Code does not specifically cover stainless steel materials. Therefore, ANSI/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities", Reference [30] is used to supplement the AISC in any areas related specifically to the structural qualification of stainless steel. Note that only the allowable stresses are used from this Code and load combinations and allowable stress factors for higher service level loads are not used.

The strainer also has several components made from thin gage sheet steel, and cold formed stainless sheet steel. Therefore, SEI/ASCE 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members", (Reference [31]) is used for certain components where rules specific to thin gage and cold form stainless steel should be applicable. The rules for Allowable Stress Design (ASD) as specified in Appendix D of this code are used. This is further supplemented by the AISI Code (Reference [22]) where the ASCE Code is lacking specific guidance. Finally guidance is also taken from AWS D1.6, "Structural Welding Code - Stainless Steel", (Reference [23]) as it relates to the qualification of stainless steel welds. Detailed acceptance criteria for each type of strainer component is provided in the sections below.

The core tube is evaluated as piping per B31.1 Paragraph 104.8 as applicable. The effects of the core tube holes on the pipe stresses are incorporated using Stress Intensification Factors (SIF) for the localized effects and effective net cross section properties for global effects.

For the perforated plates, the B31.1 Code does not provide any design guidelines as discussed above. Therefore, the equations from Appendix A, Article A-8000 of the ASME B&PV Code, Section III, 1998 Edition (Reference [3]) is used to calculate the perforated plate stresses. Note that Article A-8000 refers to Subsection NB for allowable stresses, which are defined in terms of stress intensity limits, S_m. However, in keeping with the B31.1 maximum principal stress design philosophy, principal stresses are calculated and compared to the allowables based on the ASME allowable stress limit, S, taken from ASME Section II, Part D (Reference [4]). Specific limits for each component are described in further detail below.

The edge channel and the attached perforated plate work as a combined section to resist bending loads. The effective width of the perforated plate that acts in combination with the edge channel is based on Section 6.2 of the ASCE Code (Reference [31]), which provides design guidelines for very thin stainless steel members such as the perforated plate. The effective width of the plate is limited by the width to thickness ratios such that local buckling of the plate will not occur for the compression face. The minimum spacing and edge distance required for the rivets is based on the AISI (Reference [22]) requirements for screw spacing.

The seismic stiffeners, external radial stiffeners and the mounting hardware are evaluated to AISC 9th Edition (Reference [9]) as permitted in paragraph 120.2.4 of the B31.1 Code (Reference [5]). The analysis of the anchorage to the containment concrete slab will be in accordance with the Hilti technical Guide (Reference [10]).

Load Combinations

The applicable load combinations for the strainers are those for Section 6.7.1 of DG-M10 (Reference [14]) and 6.0 of DG-M09 (Reference [11]).

Load Condition	Combination
(1a) Normal Operating	DP + DW
(1b) Normal Operating (Outage/Lift Load)	DW + LL
(2) Upset	DP + DW + WD + OBE
(3) Emergency/Faulted	DP + DW + WD + SSE

where,

DW = Dead Weight Load

LL = Live Load (additional loads on strainers during outages or during installation, live load is not applicable during operation)

WD = Weight of Debris

DP = Differential Pressure

OBE = Operating Basis Earthquake

SSE = Safe Shutdown Earthquake

Note that combination (3) is classified as Emergency Condition for all ASME Code evaluations and Faulted for all components governed by AISC and ACI Codes. Also note that wind, snow, tornado, and jet force loads are not applicable. Flood loads are considered for Load Combinations 2 and 3. Flood loads consist of the effects due to earthquake in a submerged condition (sloshing and added mass). There is no hydrostatic pressure loads associated with flooding since the flood waters are present on all sides. Thermal expansion stresses are considered negligible as described in Section 2.0.

Core tube

The core tube is evaluated as piping per B31.1 Paragraph 104.8 as applicable. Since the B31.1 does not explicitly identify how to incorporate the Emergency SSE loads, PBNP uses ASME Section III as a guide as discussed in Section 6.0 of DG-M09 (Reference [11]).

B31.1 Eq. No	Load Condition	Load Combination	Allowable Stress
11	Normal	DW	1.0 S_h
12 (OBE)	Upset	DW + OBE	1.2 S_h
12 (SSE)	Emergency	DW + SSE	1.8 S_h

Strainer Pressure Retaining Plates

For the pressure retaining plates, such as the perforated plate the B31.1 Code does not provide any design guidelines as discussed above. For the perforated plate, the equations from Appendix A, Article A-8000 of the ASME B&PV Code, Section III, 1998 Edition through 1999 Addenda (Reference [3]) is used to calculate the stresses. Note that Article A-8000 refers to Subsection NB for allowable stresses, which are defined in terms of stress intensity limits, S_m. However, in keeping with the B31.1 maximum principal stress design philosophy, principal stresses are calculated and compared to the allowables based on the ASME allowable stress limit, S.

Stress limits for the pressure retaining plates are taken from NC-3321 (Reference [3])

Load Condition	Stress Type	Allowable Stress	Design Level
Normal/Upset*	Primary Membrane Stress	1.0 S_h	Level A
	Primary Membrane (or Local) + Bending	1.5 S_h	
Emergency	Primary Membrane Stress	1.5 S_h	Level C
	Primary Membrane (or Local) + Bending	1.8 S_h	

*Allowable stresses for Upset condition may be increased by 10% as permitted by NC-3321 (Reference [3])

Strainer Structural Components

Based on the discussion provided earlier in this section, the allowable stresses on the strainer structural components is based on the AISC 9th Edition (Reference [9]). The allowable stress for the SSE Load Combinations is taken from Section 6.9 of DG M10 (Reference [14]).

Load Condition	Load Combination	Allowable Stress
Normal Operating	1a, 1b	1.0 AISC
Upset	2	1.0 AISC
Faulted	3	1.5 AISC but not to exceed 0.9 S_y

Additional details for the various types of support components are provided below .

Compression

Per Reference [30], because stainless steel does not display a single, well defined modulus of elasticity, the allowable compression stress equations from the AISC are not applicable for stainless steels. Therefore, the allowable compression stress will be based on the lower allowables from Reference [30] as opposed to those provided in the AISC Code (Reference [9]). Per Q1.5.9.2 of Reference [30], the allowable stresses for tension, shear, bending and bearing for stainless steel can be taken as the same allowables provided for carbon steel, therefore the AISC 9th Edition will be used for allowables for these types of stresses.

GTSTRUDL Code Check

Most support components are qualified using the GTSTRUDL code check features. The use of the 9th Edition Code check feature of GTSTRUDL is acceptable for this application with the exception of the allowable compression stress as described above. The effective buckling length factor, K, will be manually adjusted to account for the lower compression stress allowable. See Section 6.5.8 for additional discussion.

Edge Channels

The edge channel and the attached perforated plate work as a combined section to resist bending loads. The effective width of the perforated plate that acts in combination with the edge channel is based on Section 2.3 of the ASCE Standard for Cold-Formed Stainless Steel Structural Members (Reference [31]), which provides design guidelines for very thin members such as the perforated plate. The effective width of the plate is limited by the width to thickness ratios such that local buckling of the plate will not occur for the compression face. The minimum spacing and edge distance required for the rivets is based on the AISI (Reference [22]) requirements for screw spacing.

Welds

There are no provisions given in the B31.1 Code for the strainer structural welds to the piping components (radial stiffener to core tube). Therefore, these welds are evaluated in accordance with paragraph NC-3356(c) of the ASME B&PV Code, Section III (Reference [3]). Welds for strainer support components, such as for the seismic stiffeners to radial stiffeners, end cover connecting tabs, and those for the floor track support system, are qualified per the AISC 9th Edition (Reference [9]). AWS D1.6 (Reference [23]) was reviewed to ensure that any special qualification requirements associated with stainless steel welding were considered. Since the weld allowables provided in AWS D1.6 are essentially the same as allowed for carbon steel welds under AWS D1.1 (Reference [13]), no special adjustments are required to account for stainless steel.

Rivets

There are three areas in the strainer module where rivets are used as fasteners. The disk faces are riveted to the perforated edge channels. The gap disk is fashioned into a ring using two rivets. The sleeve that connects adjacent module core tubes together is held in place by two latches that uses four rivets each to attach to the thin gauge steel. The rivets' capacities are based on testing. From Reference [18], the capacities of the rivets are taken as the average value from six tests (six tests for shear and six tests for tension). A factor of safety is then calculated according to the ASCE Standard (Reference [31]) as supplemented by the AISI Code (Reference [22]) accounting for the capacities being found experimentally via a small sample group (n = 6). This factor of safety (FS = 2.50 per Section 6.13 of this calculation) will be used on these ultimate capacities for OBE. An increase of 1.5 is allowed for SSE, resulting in a FS/1.5 for SSE.

Mounting Hardware

Hilti Kwik-Bolt IIIs will be used to mount the strainers to the floor. The analysis and design of expansion anchors shall be in accordance with the Hilti Technical Guide (Reference [10]) however a Factor of Safety of 4 against ultimate will be used. Qualifications of the bolts/pins used to attach the strainers to the track will be based on the ASCE Standard (Reference [31]). Neither of the AISC Codes (References [9] & [30]), provide specific bolting allowables for stainless steel bolting.

4.0 ASSUMPTIONS

This calculation evaluates the Unit 1 strainers including the additional modules and new end covers associated with Unit 1 to be added under EC 12601 and EC 12603. It is also applicable for the Unit 2 strainers, including changes to be installed at a later date, provided the following assumptions hold true:

- The end cover assembly and strainers are identical to Unit 1
- New 5/8" expansion anchors at 4-1/2" embedment maintain a minimum of 6" anchor-to-anchor spacing for an interior anchor and 3" anchor-to-anchor spacing for anchors at the end of individual tracks (coupled with a min. 8-1/2" edge distance)
- New 5/8" expansion anchors at 4-1/2" embedment maintain a minimum of 5" edge distance to expansion joints in the concrete floor (coupled with a min. 8-1/2" anchor-to-anchor spacing)

Assumptions shown will be removed with revision to the calculation as part of EC 12601 - Unit 2 Additional Strainer modification.

[redacted] 10-3-2008

5.0 DEFINITIONS AND DESIGN INPUT

Define, $ksi \equiv 10^3 \cdot psi$ $kips \equiv 10^3 \cdot lbf$ $kPa := 1000 \cdot Pa$ $ORIGIN \equiv 1$

5.1 Material Properties

Material Types per Reference [6b]:

Perforated Plate:	Stainless Steel ASTM A-240, Type 304
Core Tube:	Stainless Steel ASTM A-240, Type 304
Radial Stiffeners:	Stainless Steel ASTM A-240, Type 304
Wire Stiffeners:	Stainless Steel ASTM A-493, Type 304 (Drafted to 110 ksi - 130 ksi)
Rivets:	Stainless Steel ASTM A-240, Type 304
Connecting Rods:	Stainless Steel ASTM A-276, Type 304
Nuts:	Stainless Steel ASTM A-194, Grade 8
Washers:	Stainless Steel ASTM A-240, Type 304
Spacer Sleeves:	Stainless Steel ASTM A-312, Type 304
Seismic Stiffeners:	Stainless Steel ASTM A-240, Type 304
Angle Iron:	Stainless Steel ASTM A-276, Type 304
Mounting pins:	Stainless Steel ASTM A-276, Type 304
Hitch Pins:	Stainless Steel ASTM A-580, Type 304
End Cover Assembly	Stainless Steel ASTM A-240, Type 304
Latch and Strike Plate:	Stainless Steel ASTM A-240, A-580, A-313, Type 304
Latch Rivets:	Stainless Steel ASTM A-493/A-313, Type 304

Design Temperature $T_{des} = 250°\ F$ (Reference [1])

All Type 304 Steels (Based on A-240, Type 304)

Modulus of Elasticity at 250° F (Reference [4]), $E_s := 27300 \cdot ksi$

Yield strength at 250° F (Reference [4]), $S_y := 23.6 \cdot ksi$

Ultimate Strength at 250° F (Reference [4]), $S_u := 68.6 \cdot ksi$

B31.1 Allowable Stress at 250° F (Reference [5]), $S_h := 17.2 \cdot ksi$

Note these properties are conservative for the Type 304 wire stiffeners which are drafted to a higher tensile strength than standard Type 304 stainless steels

Wire Material

The ASTM Standard (Ref. [47]) does not report a yield strength for this material as the typical application of wire is tension only. Therefore, a test was performed (Ref. [48]) to determine the yield strength of the wires (both radial and circumferential). The reported values for the yield strength are 89-112ksi. However, due to the low number of tests performed, a conservative value of 65ksi is used for the yield strength of the wire material at elevated temperatures (250°F).

Yield Strength at 250° F (Ref [48]) $S_{y.wire} := 65ksi$

Other Miscellaneous Properties

Density of stainless steel from Reference [20], $\rho_{steel} := 501 \cdot \frac{lbf}{ft^3}$

Density of carbon steel from Reference [20], $\rho_{c.steel} := 490 \cdot \frac{lbf}{ft^3}$

Poisson's Ratio from Reference [20], $\nu := 0.305$

Density of water at temperature of 68°F(Ref. [12]) $\gamma_{H20.1} := 62.4 \cdot \frac{lbf}{ft^3}$

* Density of water at temperature of 250°F(Ref. [38]) $\gamma_{H20.2} := 58.8 \cdot \frac{lbf}{ft^3}$

Coefficient of Thermal Expansion (CTE) of stainless steel, (going from 70°F to 250°F (Ref. [4]) $CTE := 9.1 \cdot 10^{-6}$

* Hydrodynamic mass is based on the density of water at temperature. Since the yield strength of stainless steel decreases with temperature faster than the density of water decreases, it is acceptable to use the lower density of water as long as the material yield strengths are also reduced for temperature.

5.2 Strainer Geometry and Dimensions

All data are per Ref. [6d] unless otherwise noted.

Perforated Plate Dimensions

Thickness of 18 gage perforated plate as per Reference [35] $t_{perf} := 0.048 \cdot in$

Hole diameter of perforated disk plate, $D_{disk.holes} := 0.066 \cdot in$ Ref. [6g]

Pitch distance between perforation holes in disk plate (Center-to-center distance) $P_{disk.holes} := 0.125 \cdot in$ Ref. [6g]

Disk Dimensions

Strainer disk size

$L1_{disk} := 33.0 \cdot in$

$L2_{disk} := 36.0 \cdot in$

Number of disks per strainer module

$N_{disk} := 10$

Strainer disk edge channel dimensions

$d_{chan} := 0.5 \cdot in$ Ref. [6g]

$b_{chan} := 0.5 \cdot in$ Ref. [6g]

Width of each middle disk assembly

$W_{disk} := d_{chan} + 2 \cdot t_{perf}$ $W_{disk} = 0.596\ in$

Width of gap spacing between consecutive disks

$W_{gap} := 1.0 \cdot in$

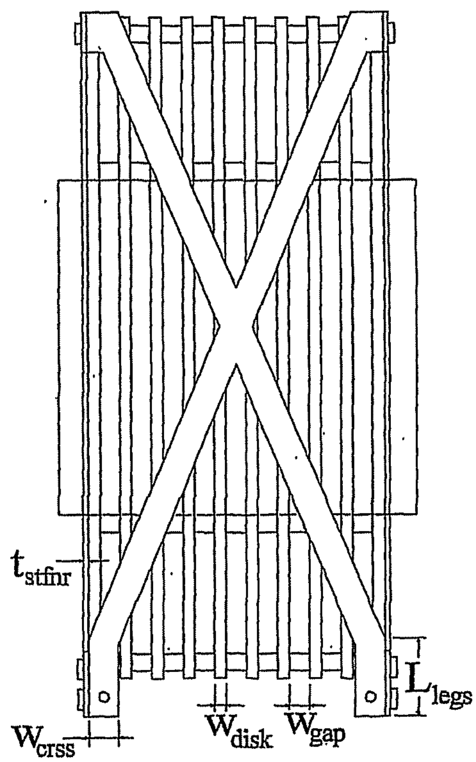

Figure 5.2-1 - Side view of Strainer Module

External Radial Stiffener and Seismic Stiffener Dimensions

The disks are supported by radial stiffeners which are welded to the core tube.

Thickness of external radial external stiffeners and debris stops	$t_{stfnr} := 0.375 \cdot in$	Ref. [6f]
Width of external radial stiffeners	$w_{stfnr} := 1.5 \cdot in$	
Width of debris stop	$w_{d.stop} := 0.84375 \cdot in$	
Outer diameter of the debris stop	$OD_{debris} := 17.565 \cdot in$	
Width of top and bottom external radial stiffener ends	$w_{end} := 2.0 \cdot in$	
Length of top stiffener ends	$L_{T.end} := 2.5 \cdot in$	
Length of bottom stiffener ends	$L_{B.end} := 4.5 \cdot in$	
Length of the support legs	$L_{legs} := 4.5 \cdot in$	
Width of support legs and seismic stiffeners	$w_{crss} := 1.5 \cdot in$	
Thickness of support legs and seismic stiffeners	$t_{crss} := 0.375 \cdot in$	Ref. [6f]
Seismic stiffener to radial stiffener weld thickness	$t_{w.cb} := 0.1875 \cdot in$	
Seismic stiffener to radial stiffener weld length (on either side of tab)	$w_{w.cb} := 1 \cdot in$	

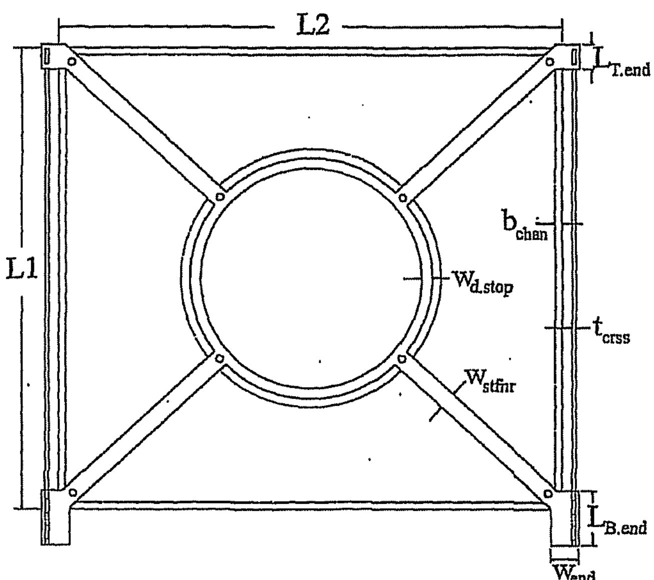

Figure 5.2-2 - End view of Strainer Module

Connecting Rod Dimensions

Number of connecting rods		$N_{rod} := 8$	
Connecting rod diameter		$OD_{rod} := 0.5 \cdot in$	Ref. [6f]
Connecting Rod tensile diameter	$OD_{tens} := OD_{rod} - \frac{0.9743 \cdot in}{13}$	$OD_{tens} = 0.425\,in$	Ref. [9]
Outside diameter of spacers (1/2" ID, SCH 80)		$OD_{spacer} := 0.84 \cdot in$	Ref. [9]
Thickness of spacers (1/2" ID, SCH 80)		$t_{spacer} := 0.147 \cdot in$	Ref. [9]
Eccentricity between edge of disk and outer connecting rod		$e_{rod} := 0.9375 \cdot in$	
Connecting rod tightening torque		$T_{rod} := 20 \cdot ft \cdot lbf$	
Diameter of centerline of inner tension rods		$BC_{rod} := 17.254 \cdot in$	

Core Tube Dimensions

Outer diameter of perforated core tube		$OD_{tube} := 15.815 \cdot in$	
Corrosion/Fabrication Allowance		$t_{ca} := 0.0 \cdot in$	
Core tube wall thickness (16 ga.)		$t_{16ga} := 0.0595 \cdot in$	Ref. [35]
Core tube wall thickness after allowance	$t_{tube} := t_{16ga} - 2 \cdot t_{ca}$	$t_{tube} = 0.0595\,in$	Ref. [6f]
Core tube extension beyond last disk face		$L_{stub} := 2.25 \cdot in$	
Outer diameter of disk gap		$OD_{gap} := 18.19 \cdot in$	
Number of rows of core tube holes		$N_{hole} := 5$	Ref. [6e]
Number of holes per row		$N_{hole.circ} := 4$	Ref. [6e]
Radial stiffener to core tube weld thickness		$t_{w.ct} := 0.0625 \cdot in$	
Radial stiffener to core tube weld length (per individual weld)		$w_{w.ct} := 1.5 \cdot in$	
The orientation of the hole along the circumference		$\phi := \begin{pmatrix} 0 \\ 90 \\ 180 \\ 270 \end{pmatrix} \cdot deg$	Ref. [6e]

Rivet Dimensions

Number of edge channel rivets per disk side (excluding corner rivets)		$N1_{rivet} := 10$	$N2_{rivet} := 11$
End cover, face/gap disk rivet head diameter (item #'s PR64FFP and PR62FFP, respectively. See Ref. [29])		$c_{disk.rivet} := 0.375 \cdot in$	Ref. [6f] Ref. [6h]
Sleeve Rivet diameter (1/8" Stainless Steel Rivets)		$c_{slv.rivet} := 0.125 \cdot in$	

Rivet Dimensions (continued)

Number of intermediate disk face rivets		$N_{rivet.face} := 0$	
Number of inner gap rivets holding the hoop together		$N_{rivet.hoop} := 2$	Ref. [6g]
Number of rivets to attach latches and strikes to sleeve connector		$N_{rv.latch} := 8$	Ref. [6h]
Eccentricity between the edge channel rivets and the adjacent edge of disk		$e_{rivet} := 0.25 \cdot in$	
Offset from line connecting center of core tube and center of outer rod (Refer to subsection Internal Wire Stiffeners in Section 6.1 for more detail)		$e_{off} := 1.25 \cdot in$	

Internal Wire Stiffener Dimensions (All data per Ref. [6g] unless otherwise noted)

Number of intermediate circumferential stiffeners		$N_{circ} := 1$	
Diameter of radial wire stiffeners (7 ga)		$d_{wire.rad} := 0.177 \cdot in$	Ref. [6b]
Diameter of circumferential wire spacers (8 ga)		$d_{wire.circ} := 0.162 \cdot in$	Ref. [6b]
Inner circumferential stiffener width	$L_{circ.in} := OD_{tube} + 1.5 \cdot in$	$L_{circ.in} = 17.32\,in$	
Outer circumferential stiffener width (Side 1)	$L1_{circ.out} := L1_{disk} - 2 \cdot e_{rod}$	$L1_{circ.out} = 31.125\,in$	
Outer circumferential stiffener width (Side 2)	$L2_{circ.out} := L2_{disk} - 2 \cdot e_{rod}$	$L2_{circ.out} = 34.125\,in$	
Corner distance for outer circumferential		$L_{circ.cor} := 1.5 \cdot in$	

End Cover Assembly Dimensions (Dimensions per Ref. [6y])

Thickness of end cover		$t_{back.pl} := 0.5 \cdot in$
Diameter of back plate		$OD_{back.pl} := 19.3150in$
Diameter of sleeve		$OD_{sleeve.ec} := 15.815in$
Thickness of sleeve	$t_{sleeve.ec} := t_{tube}$	$t_{sleeve.ec} = 0.06\,in$
Length of base plate		$L_{base.pl} := 14in$
Thickness of base plate		$t_{base.pl} := 0.5in$
Length of tube steel support		$L_{ts.ec} := 28.2095in$
Length of sleeve		$L_{sleeve.ec} := 1.5in$
Eccentricity between edge of base plate and anchor bolt		$e_{base.pl} := 1.25in$
Height of stiffener		$h_{stiff} := 3in$
Thickness of stiffener		$t_{stiff} := 0.5in$
Size of tube steel support		$w_{ts.ec} := 4in$

End Cover Assembly Dimensions (continued)

Minimum distance from the expansion anchor bolt postion parallel to the base plate edges. (Note that the holes can be drilled any where between the two positions shown in section 6.11)	$e_{b.pl} := 1.25in$	
Weld thickness for all base plate connections of end cover assembly	$t_{w.ec.bp} := 0.25in$	
Weld thickness of tube steel to the back plate	$t_{w.ec.ts} := 0.25in$	
Weld thickness of sleeve to the back plate	$t_{w.ec.sleeve} := 0.0625in$	
Tolerance for the offset for connection between the back plate and the tube steel in the horizontal direction	$d_{offset} := 0.5in$	
Anchor Bolts for end cover assembly	$OD_{hkb.ec} := 0.5in$	

Other Miscellaneous Dimensions

Diameter of mounting pin connecting the strainer to the angle iron track	$OD_{pin} := 0.5 \cdot in$	Ref. [6h]
Angle iron thickness	$t_{angle} := 0.25 \cdot in$	Ref. [6i]
Length of vertical leg of the angle iron track	$L_{vert.leg} := 2 \cdot in$	Ref. [6i]
Eccentricity from bolt connection to bottom of angle	$e_{bolt} := 1.125 \cdot in$	Ref. [6i]
Eccentricity from corner of angle to anchor bolt	$e_{hkb.1} := 1.5 \cdot in$	
Eccentricity from edge of angle leg to anchor bolt	$e_{hkb.2} := 1.5 \cdot in$	
Span between two adjacent anchor bolts	$L_{hkb} := 19.9567 \cdot in$	Ref. [6i]
Eccentricity between two adjacent module supports	$e_{sprt} := 6.5 \cdot in$	Ref. [6i]
Length of alternate angle iron segment in case of rebar interference:	$L_{alt} := 4.5 \cdot in$	Ref. [6c]
Alternate angle iron segment to angle iron track weld length (full)	$w_{w.alt} := 2 \cdot in$	Ref. [6c]

Other Miscellaneous Dimensions (cont'd)

Alternate angle iron segment weld thickness		$t_{w.alt} := 0.1875 \cdot in$	Ref. [6c]
Diameter of hitch pin		$OD_{hitch} := 0.177 \cdot in$	Ref. [6b]
Diameter of Hilti Kwik anchor bolt		$OD_{hkb} := 0.625 \cdot in$	Ref. [6c]
Diameter of core tube connection sleeve		$OD_{sleeve} := 15.8723 \cdot in$	Ref. [6h]
Thickness of sleeve connecting two adjacent modules (22 ga. See Ref. [35])		$t_{sleeve} := 0.0293 \cdot in$	Ref. [6h]
Width of sleeve connecting two adjacent modules		$w_{sleeve} := 3.5 \cdot in$	Ref. [6h]
Number of latches per sleeve		$N_{latch} := 2$	Ref. [6h]
Span between two module supports for a given module		$L_{sprt} := 13.4567 \cdot in$	Ref. [6i]

Pool Boundaries *(All data per Ref. [6a] unless otherwise noted)*

Minimum height of the water above the floor		$H_w := 38 \cdot in$	
Gap between the bottom of the strainer and the floor		$g_f := 3 \cdot in$	
Gap between the top of the strainer and the minimum water level surface		$g_t := 2 \cdot in$	
Approximate distance from containment wall/floor interface to adjacent strainer train (Unit 1 controls)		$e_w := 6 \cdot in$	Ref. [6j]
Angle of the reactor containment wall	$\alpha_{wall} := \text{atan}\left(\frac{10 \cdot ft}{3 \cdot ft}\right)$	$\alpha_{wall} = 73.30\ deg$	Ref. [6j]
Minimum average gap between the side of the strainer and the nearest wall (Unit 1 controls)	$g_w := e_w + \frac{0.5 \cdot L1_{disk} + g_f}{\tan(\alpha_{wall})}$	$g_w = 11.85\ in$	Ref. [6j] and Ref. [6a]

Strainer Trains

The hole/slot distributions along the length the core tube are given in terms of dimensions H (the width of the slot or the diameter of the hole) and L2 the length of the slot. The length of the slot (L2) is orientated along the axis of the core tube. There are four holes around the circumference of each row. There are N_{hole} number of rows. H is provided in array format and L2 and L_{lig} are provided as constants (see Reference [6e]), where the rows are the hole locations, the first row being the smallest hole on the end module, and the last being the largest hole on the end module. The first column represents the holes associated with the 0 and 180 degree locations of the end the module, and the second column represents the holes associated with the 90 and 270 degree locations of the end module.

$k := 1 .. N_{hole}$ $j := 1 .. 2$

0   90 deg

$$H := \begin{pmatrix} 2.34 & 2.39 \\ 2.34 & 2.39 \\ 2.34 & 2.39 \\ 2.34 & 2.39 \\ 2.34 & 2.39 \end{pmatrix} \cdot in$$

$L2 := 2.49 \cdot in$

$L_{lig} := 0.5 \cdot in$

$r_{hole} := \min\left(\frac{H}{2}, 0.25 \cdot in\right)$

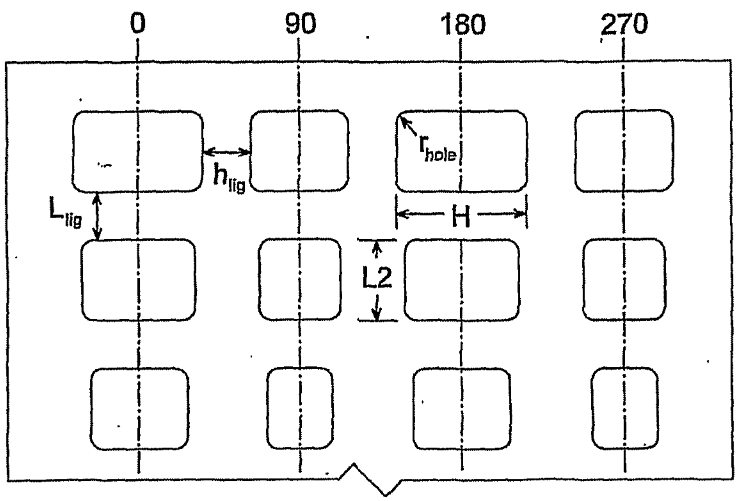

Figure 5.2-3 - Partial View of Strainer Trains

(Figure is a partial view of complete layout, see Ref. [6e])

Note the holes at 0 degrees and 180 degrees are the same size, and the holes at 90 degrees and 270 degrees are also the same size (see "Sure-Flow Strainer Trains" Reference [6e]).

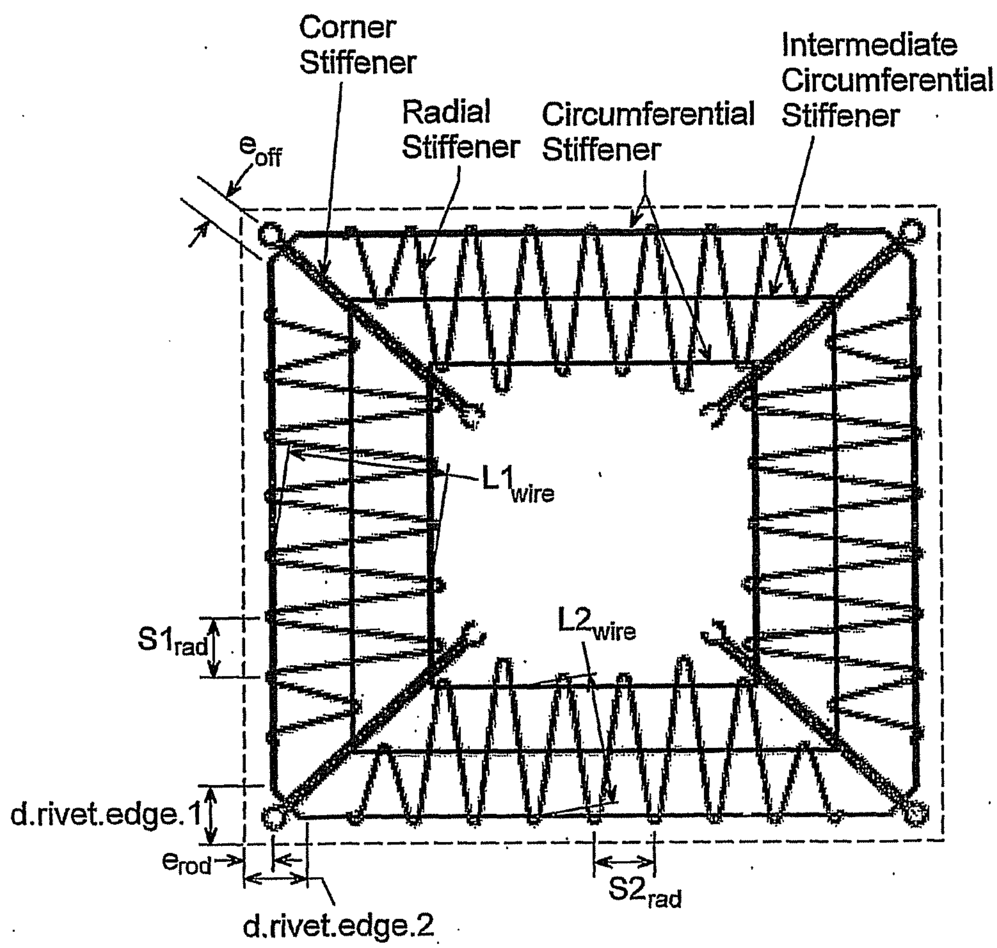

Figure 6.1-1 - Intermediate Wire Stiffener Pattern and Notation

7.0 RESULTS AND CONCLUSIONS

The results of this calculation indicate that the strainers meet the acceptance criteria for all applicable loadings. A summary of the maximum stress Interaction Ratios (calculated stress divided by allowable stress) is provided below.

Strainer Component	Ref. Section	Interaction Ratio (OBE SSE)
External Radial Stiffener (Including Debris Stops)	6.6	$IR_{rad.stfnr}^T = (0.84\ \ 0.95)$
Tension Rods	6.6	$IR_{rod}^T = (0.81\ \ 0.86)$
Edge Channels (Rims Disks)	6.6	$IR_{chan}^T = (0.62\ \ 0.80)$
Seismic Stiffeners	6.6	$IR_{seis.stfnr}^T = (0.92\ \ 0.81)$
Pipe Spacers	6.6	$IR_{spacer}^T = (0.54\ \ 0.53)$
Core Tube (Biggest Holes)	6.8	$IR_{tube}^T = (0.03\ \ 0.02)$
Perforated Plate (DP Case)	6.9.1	$IR_{face.dp}^T = (0.95\ \ 0.80)$
Perforated Plate (Seismic Case)	6.9.1	$IR_{face.bp}^T = (0.27\ \ 0.35)$
Perforated Plate (Rim Disks)	6.9.3	$IR_{edge}^T = (0.14\ \ 0.12)$
Perforated Plate (Gap Disk)	6.9.4	$IR_{gap}^T = (0.45\ \ 0.37)$
Wire Grill Stiffener	6.10	$IR_{wire} = 0.69$
End Cover Assembly Components	6.11	$IR_{ec}^T = (0.49\ \ 0.43)$
End Cover Assembly Anchor Bolts	6.11	$IR_{anc.bolt.e}^T = (0.60\ \ 0.72)$
End Cover Assembly Welds	6.12.1	$IR_{w.ec}^T = (0.31\ \ 0.23)$
Weld of Radial Stiffener to Core Tube	6.12.2	$IR_{weld.ct}^T = (0.30\ \ 0.47)$
Weld of Radial Stiffener to Seismic Stiffener	6.12.3	$IR_{weld.cb}^T = (0.51\ \ 0.50)$

RESULTS AND CONCLUSIONS (Cont.)

Strainer Component	Ref. Section	Interaction Ratio
Rim Disk Blind Rivets	6.13.1	$IR_{rv.face}{}^T = (0.13 \quad 0.12)$
Gap Disk Blind Rivets	6.13.2	$IR_{rv.gap}{}^T = (0.09 \quad 0.06)$
Mounting Pins	6.14.1	$IR_{pin}{}^T = (0.18 \quad 0.19)$
Clevis Hitch Pins	6.14.1	$IR_{hitch}{}^T = (0.56 \quad 0.66)$
Angle Iron Mounting Tracks	6.14.2	$IR_{angle}{}^T = (0.53 \quad 0.78)$
Expansion Anchors to Floor	6.14.3	$IR_{hkb}{}^T = (0.55 \quad 0.97)$
Angle Iron-to-Angle Iron Track Weld	6.14.4	$IR_{weld.alt}{}^T = (0.07 \quad 0.08)$
Module-to-module Sleeve	6.15.1	$IR_{sleeve}{}^T = (0.17 \quad 0.19)$
Module-to-module Sleeve Connection (optional Strap and Clip included)	6.15.3	$IR_{slv.con}{}^T = (0.76 \quad 0.82)$
Lift Case	6.16	$IR_{lift} = 0.26$
Outage Case	6.17	$IR_{outage} = 0.19$

8.0 REFERENCES

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[2] Point Beach Nuclear Plant Seismic Qualification Specification Sheet SQ #002243, Revision 0.

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[4] ASME B&PV Code, Section II, Part D, Material Properties, 1998 Edition, through 1999 Addenda.

[5] ANSI/ASME B31.1 Power Piping Code, 1998 Edition, through 1999 Addenda.

[6] Performance Contracting, Inc.(PCI), Sure-Flow Suction Strainer Drawings.

6a. PCI Drawing No. SFS-PB2-GA-00, "Sure-Flow Strainer Recirc Sump System Layout", Revision 2.
6b. PCI Drawing No. SFS-PB2-GA-01, "Sure-Flow Strainer General Notes", Revision 7.
6c. PCI Drawing No. SFS-PB2-GA-02, "Sure-Flow Strainer A Strainer", Revision 9.
6d. PCI Drawing No. SFS-PB2-PA-7100, "Sure-Flow Strainer Module Assembly", Revision 1.
6e. PCI Drawing No. SFS-PB2-PA-7101, "Sure-Flow Strainer Trains", Revision 1.
6f. PCI Drawing No. SFS-PB2-PA-7102, "Sure-Flow Strainer Module Assembly", Revision 3.
6g. PCI Drawing No. SFS-PB2-PA-7103, "Sure-Flow Strainer Sections and Details", Revision 0.
6h. PCI Drawing No. SFS-PB2-PA-7105, "Sure-Flow Strainer Sleeves/Cover/Supports/Pins", Revision 4.
6i. PCI Drawing No. SFS-PB2-PA-7150, "Sure-Flow Strainer Mounting Track A1/B1", Revision 2.
6j. PCI Drawing No. SFS-PB1-GA-00, "Sure-Flow Strainer Recirc Sump System", Revision 9.
6k. PCI Drawing No. SFS-PB2-PA-7106, "Sure-Flow Strainer End Cover", Revision 1.
6l. PCI Drawing No. SFS-PB1-GA-01, "Sure-Flow Strainer General Notes", Revision 12.
6m. PCI Drawing No. SFS-PB1-GA-02, "Sure-Flow Strainer A Strainer", Revision 9.
6n. PCI Drawing No. SFS-PB1-PA-7100, "Sure-Flow Strainer Module Assembly", Revision 4.
6o. PCI Drawing No. SFS-PB1-PA-7101, "Sure-Flow Strainer Trains", Revision 5.
6p. PCI Drawing No. SFS-PB1-PA-7102, "Sure-Flow Strainer Module Assembly", Revision 3.
6q. PCI Drawing No. SFS-PB1-PA-7103, "Sure-Flow Strainer Sections and Details", Revision 3.
6r. PCI Drawing No. SFS-PB1-PA-7105, "Sure-Flow Strainer Sleeves/Cover/Supports/Pins", Revision 12.

6s. PCI Drawing No. SFS-PB1-PA-7150, "Sure-Flow Strainer Mounting Track A1, B1", Revision 1.

6t. PCI Drawing No. SFS-PB1-PA-7153, "Sure-Flow Strainer Monting Track A3, B3", Revision 3.

6u. PCI Drawing No. SFS-PB1-GA-03, "Sure-Flow Strainer B Strainer", Revision 9.

6v. PCI Drawing No. SFS-PB2-GA-03, "Sure-Flow Strainer B Strainer", Revision 9.

6w. PCI Drawing No. SFS-PB1-PA-7151, "Sure-Flow Strainer Mounting Track A2, B2", Revision 2.

6x. PCI Drawing No. SFS-PB2-PA-7151, "Sure-Flow Strainer Mounting Track A2/B2", Revision 3.

6y. PCI Drawing No. SFS-PB1-PA-7152, "Sure-Flow Strainer Module End Cover Assembly", Revision 3.

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[12] "Engineering Fluid Mechanics" by John A. Roberson and Clayton T. Crowe, 2nd Edition, Rudolf Steiner Press, 1969, Library of Congress Catalog Number 79-87855.

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[14] Wisconsin Electric Guideline DG-M10, Pipe Support Guidelines, Revision 2.

[15] Wisconsin Electric Guideline DG-C03, Seismic Design Criteria Guideline, Revision 0.

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[17] "Theory of Plates and Shells" by Stephen P. Timoshenko and S. Woinowsky-Krieger, 2nd Edition, McGraw-Hill, 1959.

[18] PCI Intra -Company Correspondence from Greg Hunter, Dated February 20, 2006, Subject, "Testing of 3/16" Blind Rivets and 3/16" Closed End Rivets" (with test reports attached). (Attachment C)

[19] ASME Publication, "Pressure Vessel and Piping: Design and Analysis," Volume 2, 1972, Components and Structural Dynamics, Paper Title " Design of Perforated Plate," by O'Donnell & Langer Reprinted from Journal of Engineering for Industry, 1962.

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[24] Not Used

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[27] PCI Technical Document TDI-6007-04, "Module Debris Weight - Point Beach Nuclear Plant Units 1/2", Revision 3.

[28] Nukon Pipe ESD-TR-14B, "Latch and Strike Tensile Strength Test," August 11, 1993. (Attachment D)

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[31] ASCE Standard SEI/ASCE 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members".

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[34] Journal of Engineering Mechanics ASCE, "Added Masses of Lenses and Parallel Plates", by Sarpkaya, T., 1960. (Attachment G)

[35] Stainless Steel Sheet Thickness Table from Hendrick book. (Attachment H)

[36] Bechtel Drawing No. C-128, Containment Structure Interior Plans at El. 10'-0", EL. 21'-0", EL. 24'-8", and EL. 38'-0", Rev. 9. (Unit 1)

[37] Bechtel Drawing No. C-2128, Containment Structure Interior Plans at El. 10'-0", EL. 21'-0", EL. 24'-8", and EL. 38'-0", Rev. 8. (Unit 2)

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[41] EC No. 9355 affecting drawing "SFS-PB2-GA-02, Revision 8", Revision 0.

[42] EC No. 9364 affecting drawing "SFS-PB2-GA-03, Revision 8", Revision 0.

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[46] DIT-008 for EC 12603 and EC 12601 From Point beach 9/18/08.

[47] ASTM Standard Specification A493-85, "Stainless and Heat-resisting Steel for Cold Heading and Cold Forging - Bar and Wire".

[48] Lehigh Testing Laboratories Test No. G-4-27, dated August 3, 2007, with test reports attached. (Attachment K)

[49] Not Used.

[50] Bechtel Drawing No. C-3181, (Unit 1)

[51] Lehigh Testing Laboratories Test No. F-19-32, dated July 20, 2006 (with test reports attached) (Attachment L).

ENCLOSURE 4

NEXTERA ENERGY POINT BEACH, LLC
POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
GSI-191/GL 2004-02 (TAC NOS. MC4705/4706)
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

PERFORMANCE CONTRACTING, INC.
CALCULATION PCI-5344-S03, REVISION 4, SEPTEMBER 24, 2008
EVALUATION OF SUMP COVER AND PIPING FOR THE CONTAINMENT SUMP STRAINERS (ABRIDGED)
POINT BEACH NUCLEAR PLANT, UNIT 1

21 pages follow

Automated Engineering Services Corp.	# Calculation Package	Page 1	of 114

Calculation Number:	PCI-5344-S03		
Calculation Title:	Evaluation of Sump Cover and Piping for the Containment Sump Strainers		
Client:	Performance Contracting, Inc. (PCI)	**Station:** Point Beach	
Project Number:	PCI-5344	**Unit(s):** 1	
Project Title:	Point Beach Strainer Engineering		

Safety Related Yes ☒ No ☐

Revision	Affected Pages	Revision Description	Approval Signature / Date	Signature / Initials of Preparers & Reviewers
0	All	Initial Issue	[redacted] 07/21/06	Prepared by: [redacted] Reviewed by: [redacted]
1	1-4, 6, 11, 14-16, 25-32, 34-68, 70-105, 107 Attachment A Attachment B Attachment C	Incorporated pressure thrust load on piping due to strainer pressure imbalance. Revised sole plate design to bolt directly to floor, evaluated uplift load on sole plate from valve testing and the application of lubricants during flange bolt-ups. Minor other editorial changes. Renumbered all pages from p. 8 forward. This revision resolves AES CAR 06-006	[redacted] 1/30/07	Prepared by: [redacted] Reviewed by: [redacted]
2	1-4, 6, 26, 29-31, 34, 37, 38, 40-42, 44-47, 55-68, 70-80, 82-92, 95-98, 100-103, 105, 106, 108-112, 114 & Attachment A	Incorporated ECN's 10580, 10581, 10653 & DIT for EC 10720. Reanalyzed static analysis (Attachment A) to incorporate gaps of 3/32" at the U-bolt/pipe side of the 2-way restraints (PS3). Renumbered all pages from page 73 forward.	[redacted] 4/27/07	Prepared by: [redacted] Reviewed by: [redacted]

Revision	Affected Pages	Revision Description	Approval Signature / Date	Signature / Initials of Preparers & Reviewers
3	1-3, 69-71, 83, 85, 93-94, 110-111 Added 1A	Changed faulted shear stress allowable to agree with DG-M10 and the effective shear stress area for angle and tee sections to agree with paragraph C3 (p. 5-315) of AISC 9th Edition Commentary on the Specification for Allowable Stress of Single-Angle Members. This resolves CAR-07-004.	[redacted] 12/27/07	Prepared by: [redacted] Reviewed by: [redacted]
4	1A, 2, 3, 6, 13, 14, 26, 29-31, 37, 38, 40-42, 44-47, 55-60, 62, 63, 65-68, 70-73, 78-80, 82-88, 91-95, 97, 98, 100-103, 105, 108-112, 114 Added 44A Attachment A	Incorporated DIT003 for EC 12601 & EC 12603. Reanalyzed static analysis (Attachment A) to incorporate increase in pressure thrust load on piping due to strainer pressure imbalance.	[redacted] 9/24/08	Prepared by: [redacted] Reviewed by: [redacted]

REVIEWER'S CHECKLIST FOR DESIGN CALCULATIONS SHEET 1 of 2

STATION: Point Beach - Unit 1 **NUCLEAR SAFETY RELATED:** YES ☒ NO ☐

PROJECT NO: PCI-5344 **CLIENT:** Performance Contracting, Inc.

CALCULATION TITLE: Evaluation of Sump Cover and Piping for the Containment Sump Strainers

CALC. NO: PCI-5344-S03 **CALC. REV. NO:** 4

INDICATE THE DESIGN INPUT DOCUMENTS USED:

TYPE OF DOCUMENT	DOCUMENT ID, REV AND/OR DATE	YES	N/A	COMMENT
1. General Design Basis	3, 5, 8, 9, 19	X		
2. System Description			X	
3. Design information package from related equipment vendor			X	
4. Electrical Discipline Input			X	
5. Mechanical Discipline Input			X	
6. Control Systems Discipline Input			X	
7. Structural Discipline Input	4, 7, 12, 17, 18, 21-39	X		
8. Specifications	1, 2	X		
9. Vendor Drawings	6	X		
10. Design Standards			X	
11. Client Standards	10, 11, 13, 14	X		
12. Checked Calculations	15, 20, 29	X		
13. Other (specify)	16 (AutoPIPE Computer Program)	X		

PREPARER'S SIGNATURE: [redacted] DATE: 9/24/2008

REVIEWER'S SIGNATURE: [redacted] DATE: 9/24/2008

APPROVER'S SIGNATURE: [redacted] DATE: 9/24/2008

REVIEWER'S CHECKLIST FOR DESIGN CALCULATIONS SHEET 2 of 2

PROJECT NO: PCI-5344

CALC. NO: PCI-5344-S03, Revision 4

REVIEWER TO COMPLETE THE FOLLOWING ITEMS:	YES	NO	N/A	COMMENT
1. Has the purpose of the calculation been clearly stated?	X			
2. Have the applicable codes, standards and regulatory requirements been:				
A. Properly Identified?	X			
B. Properly Applied?	X			
3. Were the inputs correctly selected and used?	X			
4. A. Was Design Input Log used?		X		
B. If 4A is No, provide Manager's signature in Comment column to signify approval of Design Input Documents used in the calculation.				[redacted]
5. Are necessary assumptions adequately stated?			X	
6. Are the assumptions reasonable?			X	
7. Was the calculation methodology appropriate?	X			
8. Are symbols and abbreviations adequately identified?	X			
9. Are the calculations:				
A. Neat?	X			
B. Legible?	X			
C. Easy to follow?	X			
D. Presented in logical order?	X			
E. Prepared in proper format?	X			
10. Is the output reasonable compared to the inputs?	X			
11. If a computer program was used:				
A. Is the program listed on the ASL and has the SRN been reviewed for any program use limitations?	X			
B. Have existing user notices and/or error reports for the production version been reviewed as appropriate?	X			
C. Were codes properly verified?	X			
D. Were they appropriate for the application?	X			
E. Were they correctly used:	X			
F. Was data input correct?	X			
G. Is the computer program and revision identified?	X			

TABLE OF CONTENTS

Attachments

Automated Engineering Services Corp	CALCULATION SHEET	Page: 5 of 114
		Calc. No.: PCI-5344-S03
Client: Performance Contracting Inc.		Revision: 1
Station: Point Beach - Unit 1		Prepared By: [redacted]
Calc. Title: Evaluation of Sump Cover and Piping for the Containment Sump Strainers.		Reviewed By: [redacted]
Safety Related Yes [X] No [ ]		Date: 1/30/07

1.0 PURPOSE/OBJECTIVE

The purpose of this calculation is to qualify the sump cover, piping, and piping supports associated with the Performance Contracting Inc. (PCI) Suction Strainers to be installed in ~~Nuclear Management Corporation's~~ FPL ENERGY [redacted] 10/2/08 Point Beach Nuclear Plant Unit 1. This calculation evaluates, by analysis, the piping as well as the supporting structures associated with the new piping. The evaluations encompass all piping from and including the sump cover plate (sole plate) attached to the El. 8' floor slab to the strainer connections including intermediate support structures.

2.0 METHODOLOGY

The evaluations are performed using a combination of manual calculations and computerized piping using the AutoPIPE Program (Reference [16]). The piping is considered as an attachment or extension to the strainers and are therefore subject to the requirements of Strainer Design Specification PB-681 (Reference [1]). Exceptions from these requirements, if taken, are discussed and justified within this calculation.

Seismic Loads

The strainer piping is categorized as Seismic Class I equipment and is required to be operable during and after a safe shutdown earthquake (SSE) without exceeding normal allowable stresses as specified in Section 5.4.7 of DG-C03 Seismic Design Criteria Guideline (Reference [14]). Strainer Design Specification PB-681 (Reference [1]), requires the piping to be evaluated for two operating conditions. The first condition is a "dry" condition with no recirculation water inside or external water present. The second condition is a submerged "wet" condition with recirculation water. For the seismic evaluation the piping will be considered submerged and full of water. The water level is considered to be a minimum of 3'-2" above the 8' floor elevation (El. 11'-2"). The piping "dry" state with its associated mass being much less, will not be considered as it is less severe than the "wet" state.

Per the specification, the seismic evaluation is required to take into account any seismic slosh (analyzed at the seismic worst-case water level) of the recirculation water. Based on Reference [20], because of the negligible load magnitudes, it is determined that the seismic slosh loads in PWR containments are insignificant by comparison with other seismic loads. Therefore, seismic slosh loads are neglected from the pipe stress analysis. Note that the sloshing calculation of Reference [20] is done for the Prairie Island strainer project and it is representative for all PWR containments in general, and therefore, it is applicable for use in this calculation. The "wet" strainer operating condition will consider the strainer assemblies submerged in still water at the seismic worst-case water level when subjected to seismic inertial loads. The inertial effects of the added hydrodynamic mass due to the submergence of the piping is considered.

The piping is seismically qualified using the response spectra method. The applicable seismic spectra are provided in Seismic Qualification Specification Sheet SQ-002243 (Reference [2]) These loads are applied to the piping through base motion response spectra as detailed in the Seismic Design Criteria Guideline DG-C03 (Reference [14]).

All piping is located on the 8' floor elevation of the containment. The response spectrum chosen is for the 6.5' elevation of the containment. The containment liner plate is located at the 6.5' elevation and there is an additional 1.5' of concrete on top of the liner plate. The slab between the 6.5' elevation and the 8' elevation is very rigid. Thus it is appropriate to use the response spectrum for the 6.5' elevation. The vertical direction response spectrum is 2/3 the value of the maximum ground horizontal response spectra.

The piping is considered as vital piping and the damping values for seismic loads is taken as 0.5% for both the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE) as required by Seismic Design Guide DG-C03. The response spectra inputs are for the OBE environment. For evaluating stresses, displacements, loads, etc., for the maximum credible earthquake (SSE), the values obtained from the OBE analysis are to be increased by a factor of 2.0 (Reference [11]).

The piping is excited in each of the three mutually perpendicular directions, two horizontal and one vertical. Per Reference [11], the modal combination is performed by the use of the double sum method to account for the effects of modal coupling in the response (i.e. closely spaced modes). An earthquake duration of 30.24 seconds was used in the analysis per DG-C03, Appendix C. Appendix N of the ASME code indicates that the maximum accelerations generally occur in the first 10 seconds. Two analysis were run - one with 10 sec and one with 30.24 sec. Since the results were the same, the analysis with 10 seconds is the official documented seismic analysis. Responses due to the three spatial components are combined by SRSS. (Reference [11], paragraph 5.6.5). The cutoff frequency is taken at 30 hz or a minimum of 5 modes are included.

Zero Period Acceleration (ZPA) residual mass effects are considered since they may significantly affect the piping. The ZPA response is combined with the response spectra response by SRSS.

Since all piping is supported from the same El. 8' floor slab, there are no relative seismic anchor movements.

Operating Loads

Operating loads are comprised of weight, thermal expansion and pressure loads.

The thermal expansion is taken at a temperature equal to the maximum operational inlet temperature to the RH Exchangers of 250 °F (Reference [1]). Small gaps (3/32") are modeled on the u-bolt side only of the two-way restraints (Type PS3) on the "B" train piping (Reference [37]. These gaps were modeled to reduce the high thermal loads encountered due to the several bends associated with the "B" train piping. The design drawings (Ref. [6b]) ensure that these gaps will be available. Note the Autopipe model was rerun to account for these modified gaps.

Because the attached piping is connected to the strainer with flexible joint it essentially behaves as an open ended system, this pressure differential will also create an axial thrust force on the piping. The maximum differential pressure load acting on the piping is the hydrostatic pressure associated with the maximum allowed head loss through the debris covered strainers. This is defined as 10ft of 68 °F water in Reference 39.

Software

MathCad software is used to generate most of the calculations. All MathCad calculations are independently verified for accuracy and correctness as if they were manually generated. AutoPIPE Version 8.05 is used for the piping analysis. AutoPIPE Version 8.05 is verified and validated under the AES QA program as documented in the AES validation and maintenance files (*Reference [16]*). Because the AutoPIPE Version 8.05 only performs piping evaluations using the 2001 Edition of the B31.1 Code instead of the required 1998 Edition, a reconciliation of the 2001 Code to the older 1998 Code is performed.

The only provisions of the code that could potentially affect the results of the piping analysis are changes in material properties and design equation provisions. A review of the codes and the material specifications shows that the only physical properties of material that affect the design of code items are the minimum yield, the tensile strengths and the coefficient of thermal expansion because these are the basis for the allowable stresses and the tabulated "E" and "α" values at temperature. As long as the specified tensile properties of the material have not changed, use of the later Edition does not affect the end result.

The material allowables stresses are included manually into AutoPIPE based on the ASME B31.1 - 1998 Edition, which is the design code for pipe stress analysis. In addition, a review of the two the codes was performed to identify revisions to the design equation provisions and to determine if any material properties associated with "E" and "α" had changed. There have been no design dependent revisions to the piping material and to the design code equations. The flexibility and stress intensification factors, and the method for combining moments are the same for both code editions. Therefore, the results between the two code editions will be identical.

3.0 ACCEPTANCE CRITERIA

The strainer suction piping shall meet the requirements of the strainer design specification PB-681 (Reference [1]). As stated in PB-681, the detailed evaluations are to be performed using the rules, as applicable, of ANSI/ASME B31.1 Power Piping 1998 Edition (Reference [5]).

The piping supports, baseplates and other mounting hardware is evaluated to AISC 9th Edition as permitted in paragraph 120.2.4 of the B31.1 Code. Additional guidance is also taken from other codes and standards where the AISC does not provide specific rules for certain aspects of the design. For instance, the cover plates, stiffeners angles, support components are made from stainless steel materials. The AISC Code does not specifically cover stainless steel materials. Therefore, ANSI/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities", Reference [25] is used to supplement the AISC in any areas related specifically to the structural qualification of stainless steel. Note that only the allowable stresses are used from this Code and load combinations and allowable stress factors for higher service level loads are not used.

SEI/ASCE 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members", (Reference [24]) is used for certain components (stainless steel bolts and pins) since the AISC does not provide specific bolting allowables for stainless steel bolting. The rules for Allowable Stress Design (ASD) as specified in Appendix D of this code are used. Finally guidance is also taken from AWS D1.6, "Structural Welding Code - Stainless Steel", (Reference [26]) as it relates to the qualification of stainless steel welds. Detailed acceptance criteria for each type of strainer component is provided in the sections below.

Load Combinations

The applicable load combinations for the piping are those from Section 6.0 of DG-M09 (Reference [11]).

Load Condition	Combination
(1) Normal	P + DW
(2) Upset	P + DW + OBE
(3) Emergency/Faulted	P + DW + SSE
(4) Thermal	T1

where,

DW = Dead Weight Load

P = Differential Pressure

OBE = Operating Basis Earthquake

SSE = Safe Shutdown Earthquake

T1 = Thermal Expansion

The thermal expansion stresses are based on a stress range from the ambient condition of 70 °F to the maximum operating condition of 250 °F (ΔT = 180 °F).

Piping

The piping is evaluated in accordance with ANSI B31.1 Paragraph 104.8 as applicable. Since the B31.1 does not explicitly identify how to incorporate the emergency SSE loads, PBNP uses ASME Section III as a guide as discussed in Section 6.0 of DG-M09 (Reference [11]).

B31.1 Eq. No	Load Condition	Stress Combination	Allowable Stress
11	Normal (Sustained)	P + DW	1.0 S_h
12 (OBE)	Upset (Occasional)	P + DW + OBE	1.2 S_h
12 (SSE)	Emergency (Occasional)	P + DW + SSE	1.8 S_h
13	Thermal (Displacement)	T1	1.0 S_A

Flanges

Since specific detailed guidance is not provided in B31.1, the bolted flange connections at each end of the piping elbows will be evaluated in accordance with ASME Section III, Appendix L (Reference [8]) guidelines. The flange bolts are qualified to the criteria presented in ASME III, Appendix L (Reference [8]). Note that these are non-standard flanges which do not meet the generic requirements of B31.1 (such as weld size). As stated in the forward of of the B31.1 Code (Reference [5]), "a designer who is capable of a more rigorous analysis than is specified in the Code may justify a less conservative design, and still satisfy the basic intent of the Code." Use of a detailed stress evaluation of the flange and the flange weld, based on ASME analysis equations, certainly falls within this category of satisfying the basic intent of the Code.

Piping Support Structural Components

The allowable stresses on the piping support components are based on the AISC 9th Edition (Reference [9]). Also, the allowables stresses for the sump sole plate tabs, bolts, and welds are based on the AISC 9th Edition. The allowable stress for the SSE Load Combinations is taken from Section 6.9 of DG M10 (Reference [13]).

Load Condition	Load Combination	Allowable Stress
Normal	DW + T1	1.0 AISC
Upset	DW + OBE + T1	1.0 AISC
Faulted	DW + SSE + T1	1.5 AISC but not to exceed 0.9 S_y

Compression

Per Reference [25], because stainless steel does not display a single, well defined modulus of elasticity, the allowable compression stress equations from the AISC are not applicable for stainless steels. Therefore, the allowable compression stress will be based on the lower allowables from Reference [25] as opposed to those provided in the AISC Code (Reference [9]). Per Q1.5.9.2 of Reference [25], the allowable stresses for tension, shear, bending and bearing for stainless steel can be taken as the same allowables provided for carbon steel, therefore the AISC 9th Edition will be used for allowables for these types of stresses.

Welded Joints

Allowable stresses for piping welds, such as the flange fillet welds, are per ASME Section III (Reference [8]), Paragraph NC-3356. IWA welds are in accordance with ASME Code Case N-318-5 (Reference [19]). The allowable stresses for all other welds are based on the AISC 9th Edition (Reference [9]). AWS D1.6 (Reference [26]) was reviewed to ensure that any special qualification requirements associated with stainless steel welding were considered. Since the weld allowables provided in AWS D1.6 are essentially the same as allowed for carbon steel welds under AWS D1.1, no special adjustments are required to account for stainless steel. The allowable stress for the SSE Load Combinations is taken as 1.5 times the AISC weld material allowable per Reference [13].

Integral Welded Attachment Evaluation

The localized stresses developed in the pipe due to the integral welded attachments (shear lugs) are added to the stresses calculated by AutoPIPE and compared to B31.1 allowables. ASME Code Case N-318-5 (Reference [19]) is used to calculate the local stresses since this is the latest version of the Code Case available.

Mounting Hardware

Hilti Kwik-Bolt IIIs are used to mount the support baseplates to the floor. The analysis and design of expansion anchors shall be in accordance with the Hilti Technical Guide (Reference [18]), however, a Factor of Safety of 4 against ultimate loads will be used. Prying factors are calculated in accordance with DG-C01 (Reference [10]). Qualifications of the stainless steel bolts/pins used to attach the saddle plates to the structural angles is based on the ASCE Standard (Reference [24]). The AISC Code (References [9]) does not provide specific bolting allowables for stainless steel bolting.

4.0 ASSUMPTIONS

None.

5.0 DEFINITIONS AND DESIGN INPUT

Define, $ksi \equiv 10^3 \cdot psi$ $kips \equiv 10^3 \cdot lbf$ $ORIGIN \equiv 1$ $psi \equiv 1 \cdot \frac{lbf}{in^2}$

5.1 Material Properties

The specific materials for the piping and support components are taken from Reference 6m

Piping:	Stainless Steel ASTM A312, Type 304 or Type 304L (Dual Certified)
Pipe Fittings	Stainless Steel ASTM A240, Type 304 or A774, Type 304L (Dual Certified)
Structural Steel:	Stainless Steel ASTM A276, Type 304
Flange:	Stainless Steel ASTM A-240, Type 304
Flange Bolting:	Stainless Steel ASME A-193, Gr. B8, Class II
Design Temperature	$T_{des} = 250$ °F (Reference [1])

Properties for the pipe components and support structural components are taken from ASME/ANSI B31.1, Power Piping Code, 1998 Edition (Reference [5]). Yield strength values for support structural components and flange bolting properties are not available in ANSI B31.1 Code and are taken from ASME B&PV Code, Section II, Part D (Reference [4]). For Dual Certified materials only the controlling properties are used.

Yield strength value for stainless steel A240 Type 304 material at 250 °F:	$S_{Y304} := 23.6 \cdot ksi$	(Ref. [4])
Modulus of Elasticity of stainless steel material at 250 °F:	$E := 27300 \cdot ksi$	(Ref. [5])
Allowable pipe stress at design temperature (250 °F),	$S_h := 17.20 \cdot ksi$	(Ref. [5])
Allowable design stress for flange at design temperature (250 °F),	$S_f := 17.20 \cdot ksi$	(Ref. [5])
Allowable bolt stress at design temperature (250 °F),	$S_b := 25.0 \cdot ksi$	(Ref. [4])
Modulus of Elasticity (flange)	$E_f := 27300 \cdot ksi$	(Ref. [5])
Modulus of Elasticity (bolts)	$E_b := 27300 \cdot ksi$	(Ref. [4])

Other Miscellaneous Properties

Density of stainless steel (Ref. [28]).	$\rho_{steel} := 501 \cdot \frac{lbf}{ft^3}$
Poisson's ratio of stainless steel (Ref. [28]).	$\nu := 0.305$
Density of water at temperature of 68 °F (Ref. [12])	$\gamma_{H20} := 62.4 \cdot \frac{lbf}{ft^3}$

5.2 Pipe Geometry and Dimensions

Pipe Dimensions

Outer diameter of pipe (Ref. [6b]) $OD_{pipe} := 16.0 \cdot in$

Pipe wall thickness (sch.10) (Ref. [6b]) $t_{pipe} := 0.25 \cdot in$

Inside diameter of pipe: $ID_{pipe} := OD_{pipe} - 2 \cdot t_{pipe}$ $ID_{pipe} = 15.50 \cdot in$

Radius of pipe: $r := \frac{OD_{pipe}}{2}$ $r := 8.0 \cdot in$

Corrosion Allowance/Fabrication Tolerance $t_{ca} := 0.0 \cdot in$

Pool Boundaries

Length from top of floor to centerline of pipe (Ref. [6a]) $c_f := 19.5 \cdot in$

Minimum height of the water above the floor (Ref. [6a]) $H_w := 38 \cdot in$

Distance (left side) from wall to pipe centerline (see Section 6.3.1) $c_{wl} := 13.85 \cdot in$

Distance (right side) from wall to pipe centerline (see Section 6.3.1) $c_{wr} := 24 \cdot in$

Flange Dimensions

Outer diameter of flange at top of elbow (Ref. [6f]) $OD_{flange} := 25.0 \cdot in$

Inside diameter of flange at top of elbow (Ref. [6f]) $ID_{flange} := 18.125 \cdot in$

Flange thickness (Ref. [6f]) $t_{flange} := 0.25 \cdot in$

Outer diameter of 16 pipe in-line flanges (Ref. [6b]) $OD_{flg\_16} := 23.5 \cdot in$

Inside diameter of 16 pipe in-line flanges (Ref. [6b]) $ID_{flg\_16} := 16.125 \cdot in$

Automated Engineering Services Corp	CALCULATION SHEET	Page: 27 of 114
		Calc. No.: PCI-5344-S03
Client: Performance Contracting Inc.		Revision: 1
Station: Point Beach - Unit 1		Prepared By: [redacted]
Calc. Title: Evaluation of Sump Cover and Piping for the Containment Sump Strainers		Reviewed By: [redacted]
Safety Related Yes [X] No [ ]		Date: 1/30/07

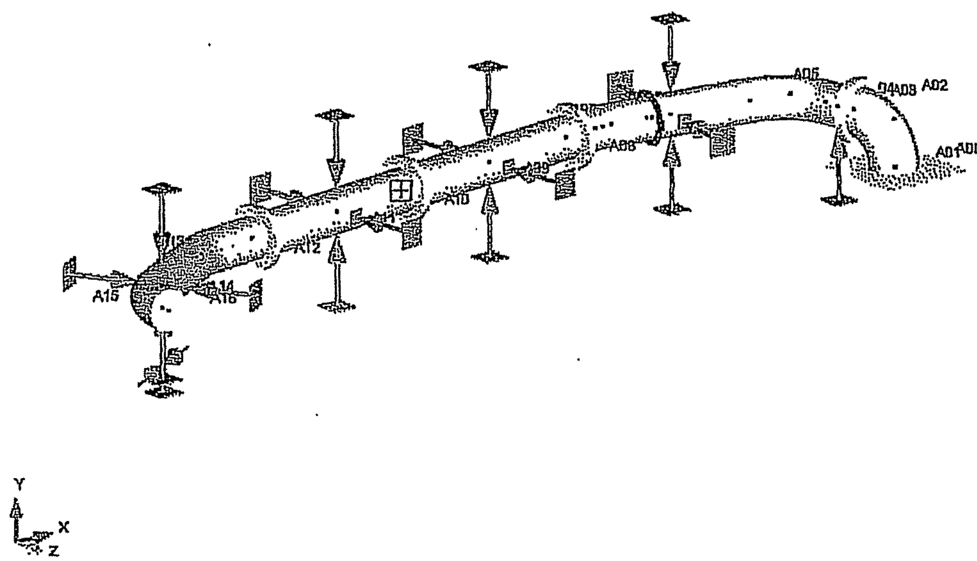
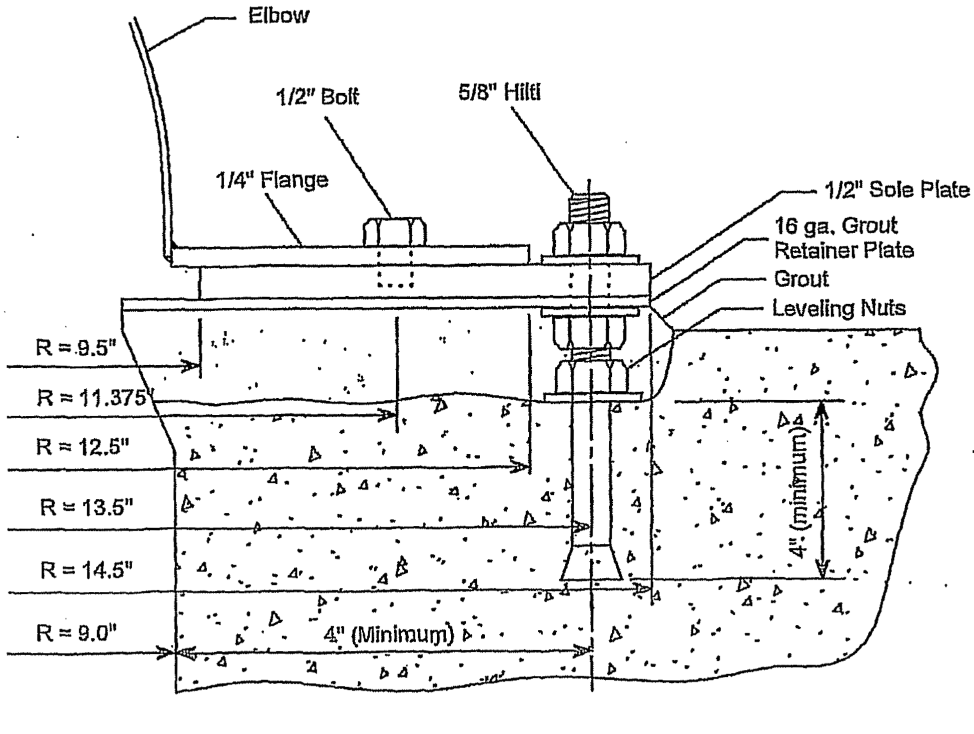


Figure 6.4.1 - Model Plot of "B" Strainer Pipe

Sole Plate Connection

As shown in figure below the connection consists of two parts. The fabricated pipe flange is identical to the flange on the opposite side of the elbow, the 1/2" annular sole plate is held down by twelve (12) 5/8" Hilti III expansion anchors (Reference [6c]).

Note that the 4" minimum distance to the edge of the sump drain concrete opening as shown in the sketch below has been reduced to a minimum of 3" in EC 10581 (Reference [35]). The centerline of the bottom end of the elbow and the associated base ring may be offset a maximum of 1" from the centerline of the sump drain pipe sleeve during installation to avoid interferences.



All three types of flanges (in-line, top of elbow, sole plate) will be analyzed concurrently using arrays. Loads for the in-line flanges will be divided into Normal/Upset and Emergency/Faulted loads, but enveloped between all flange pairs. Dimensional parameters are adjusted as required for each type of flange.

7.0 RESULTS AND CONCLUSIONS

A summary of the maximum calculated piping stresses is shown in Section 6.4. Calculated support component stresses are shown in Section 6.7. The interaction ratio for the pipe stresses, flanges, sole plate, and supports is shown below:

Pipe Stresses

B Strainer Pipe $IR_{Bpipe} := \max(IR_{B11}, IR_{B12B}, IR_{B12C}, IR_{B13})$ $IR_{Bpipe} = 0.14$

Stress Summary for other Components

Component	Ref. Section	Interaction Ratio	
Flanges			
Flange Bolting	6.5	$IR_{bolt1} = \begin{pmatrix} 0.68 \\ 0.61 \\ 0.77 \end{pmatrix}$	In-line Flanges Top of Elbow At Sole Plate
Flange Bending	6.5	$IR_{flange1} = \begin{pmatrix} 0.88 \\ 0.38 \\ 0.95 \end{pmatrix}$	
Flange Weld to Pipe	6.5	$IR_{w1} = 0.24$	
Missing Bolts *See page 45 for explanation. BAW 10/2/08*			
Flange Bolts	6.5	$IR_{bolt.missing} = 0.93$	
Flange Bending	6.5	$IR_{flange.missing} = 1.00$	
Sole Plate Connection			
Sole Plate	6.6	$IR_{sole.plate} = \begin{pmatrix} 0.17 \\ 0.27 \end{pmatrix}$	Normal/Upset Emergency/Faulted
Sole Plate Expansion Anchors	6.6	$IR_{spl.anchor} = 0.84$	

Component	Ref. Section	Interaction Ratio
Type PS1/PS2 Restraint		
Angle Normal Stress	6.7	$IR_{ang\_norm} = \begin{pmatrix} 0.76 \\ 0.80 \end{pmatrix}$ Normal/Upset, Emergency/Faulted
Angle Shear Stress	6.7	$IR_{ang\_sh} = \begin{pmatrix} 0.12 \\ 0.13 \end{pmatrix}$
Expansion Anchors (Type PS1)	6.7	$IR_{bolt\_PS1} = 0.88$
Expansion Anchors (Type PS2)	6.7	$IR_{bolt\_PS2} = 0.94$
Baseplate	6.7	$IR_{bpl} = 0.61$
Weld of Angle to Baseplate	6.7	$IR_{weld} = \begin{pmatrix} 0.59 \\ 0.55 \end{pmatrix}$
Saddle Plate Bending	6.7	$IR_{spl\_bd} = \begin{pmatrix} 0.13 \\ 0.14 \end{pmatrix}$
Saddle Plate Shear	6.7	$IR_{spl\_sh} = \begin{pmatrix} 0.63 \\ 0.74 \end{pmatrix}$
Saddle Plate Welds	6.7	$IR_{wld\_spl} = \begin{pmatrix} 0.16 \\ 0.15 \end{pmatrix}$
Saddle Plate Pins	6.7	$IR_{pin} = \begin{pmatrix} 0.25 \\ 0.30 \end{pmatrix}$
Shear Lugs	6.7	$IR_{lugs} = \begin{pmatrix} 0.06 \\ 0.08 \end{pmatrix}$
Integral Welded Attachments	6.8.1	$IR_{PS2.iwa} = 0.29$

Type PS3 Restraint

IR shown are for Faulted Loads (SSE) versus Upset Allowables (OBE)

W6x15 Normal Stress	6.7.2	$IR_{normW6} = 0.22$
W6x15 Shear Stress	6.7.2	$IR_{shearW6} = 0.07$
Expansion Anchors	6.7.2	$IR_{bolt\_PS3} = 0.49$
Baseplate	6.7.2	$IR_{bpl\_PS3} = 0.44$
Weld of W6x15 to Baseplate	6.7.2	$IR_{weld\_PS3} = 0.10$
Angle Normal Stress	6.7.2	$IR_{ang\_normPS3} = 0.76$
Angle Shear Stress	6.7.2	$IR_{ang\_shPS3} = 0.23$
Weld of Angle to W6x15	6.7.2	$IR_{weld\_ang3x2} = 0.45$
U-Bolt Normal Load	6.7.2	$IR_{Ubolt} = 0.28$

Type PB1 Restraint

Stanchion Plate Bolts	6.7.3	$IR_{bolt\_PB1} = 0.08$
Integral Welded Attachments	6.8.2	$IR_{PB1.iwa} = 0.11$

Other Piping Components

Slip Joint	6.9	$IR_{band} = \begin{pmatrix} 0.71 \\ 0.58 \end{pmatrix}$	Upset Emerg

The evaluation of the piping and piping supports associated with the suction strainers has shown that the pipe stresses and support loads are acceptable. The piping stresses, flanges, and support component stresses are within their respective applicable limits and are therefore acceptable.

8.0 REFERENCES

[1] Point Beach Nuclear Plant Specification PB-681, "Replacement of Containment Sump Screens", Revision 2

[2] Point Beach Nuclear Plant Seismic Qualification Specification Sheet SQ #002243, Revision 0

[3] ASME/ANSI B31.1, Pressure Piping Code, 2001 Edition.

[4] ASME B&PV Code, Section II, Part D, Material Properties, 1998 Edition, through 1999 Addenda

[5] ASME/ANSI B31.1 Pressure Piping Code, 1998 Edition, through 1999 Addenda

[6] Performance Contracting, Inc.(PCI), Sure-Flow Suction Strainer Drawings

- 6a. PCI Drawing No. SFS-PB1-GA-00, "PB Unit 1 Sure-Flow Strainer, Recirc Sump System", Revision 9
- 6b. PCI Drawing No. SFS-PB1-GA-04, "PB Unit 1 Sure-Flow Strainer, Piping B Layout", Revision 6
- 6c. PCI Drawing No. SFS-PB1-GA-05, "PB Unit 1 Sure-Flow Strainer, Piping A Layout", Revision 9
- 6d. PCI Drawing No. SFS-PB1-PA-7105, "PB Unit 1 Sure-Flow Strainer, Sleeves/Covers/Supports/Pins", Revision 12.
- 6e. PCI Drawing No. SFS-PB1-PA-7160, "PB Unit 1 Sure-Flow Strainer, Sump Inlet Cover", Revision 1.
- 6f. PCI Drawing No. SFS-PB1-PA-7161, "PB Unit 1 Sure-Flow Strainer, Sump Connection Elbow A1/B1", Revision 0.
- 6g. PCI Drawing No. SFS-PB1-PA-7162, "PB Unit 1 Sure-Flow Strainer, Pipe B2", Revision 2.
- 6h. PCI Drawing No. SFS-PB1-PA-7163, "PB Unit 1 Sure-Flow Strainer, Pipe B3", Revision 1.
- 6i. PCI Drawing No. SFS-PB1-PA-7164, "PB Unit 1 Sure-Flow Strainer, Pipe B4", Revision 1.
- 6j. PCI Drawing No. SFS-PB1-PA-7165, "PB Unit 1 Sure-Flow Strainer, Pipe B5", Revision 3.
- 6k. PCI Drawing No. SFS-PB1-PA-7166, "PB Unit 1 Sure-Flow Strainer, Pipe A2", Revision 2.
- 6l. PCI Drawing No. SFS-PB1-PA-7167, "PB Unit 1 Sure-Flow Strainer, Pipe A3", Revision 2.
- 6m. PCI Drawing No. SFS-PB1-GA-01, "PB Unit 1 Sure-Flow Strainer, General Notes", Revision 12

[7] "Formulas for Natural Frequency and Mode Shape," by Robert D. Blevins,1979,Van Nostrand Reinhold.

[8] ASME B&PV Code, Section III, Division 1, Subsections NB, NC, and NF, 1998 Edition through 1999 Addenda, including Appendices.

[9] AISC Manual of Steel Construction, 9th Edition.

[10] Wisconsin Electric Guideline DG-C01,"Guidelines for Design, Qualification, and Installation of Concrete Expansion Anchors at Point Beach Nuclear Plant" (with revisions per NPM 92-0428, April 27, 1992), Revision 0

[11] Wisconsin Electric Guideline DG-M09, Design Requirements for Piping Stress Analysis, Revision 2.

[12] "Engineering Fluid Mechanics" by John A. Roberson and Clayton T. Crowe, 2nd Edition, Rudolf Steiner Press, 1969, Library of Congress Catalog Number 79-87855.

[13] Wisconsin Electric Guideline DG-M10, Pipe Support Guidelines, Revision 2.

[14] Wisconsin Electric Guideline DG-C03, Seismic Design Criteria Guideline, Revision 0.

[15] AES Calculation PCI-5344-S01, "Structural Evaluation of Containment Emergency Sump Strainers", Revision 0.

[16] AutoPipe Version 8.05 QA Release 08.05.00.16 Verification Report, AES File AES.1000.0513.

[17] Welding Formulas and Tables for Structural & Mechanical Engineers & Pipe Support Designers Published by I.V.I. Structural Design Service, Copyright 1983.

[18] Hilti Product Technical Guide, Copyright 2005.

[19] Cases of ASME Boiler and Pressure Vessel Code, Case N-318-5, "Procedure for Evaluation of the Design of Rectangular Cross Section Attachments on Class 2 or 3 Piping", April 28, 1994.

[20] AES Calculation PCI-5343-S03, "Prairie Island Strainer Sloshing Evaluation", Revision 0.

[21] Roark's Formulas for Stress and Strain, Warren C. Young, 6th Edition.

[22] "Design of Welded Structures" by Omer W. Blodgett, 1969, Library of Congress Catalog Number 66-23123.

[23] Mechanical Engineering Design by Joseph Edward Shigley and Larry D. Mitchell, McGraw Hill, 1983.

[24] ASCE Standard SEI/ASCE 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members", Copyright 2002.

[25] ANSI/AISC N690, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities" Copyright 1994.

[26] ANSI/AWS D1.6:1999, "Structural Welding Code - Stainless Steel".

[27] Bechtel Drawing No. C-128, Containment Structure Interior Plans at El. 10'-0", EL. 21'-0", EL. 24'-8", and EL. 38'-0", Rev. 9. (Unit 1)

[28] "Marks' Standard Handbook for Mechanical Engineers", Avallone & Baumeister, 9th Edition, McGraw-Hill

[29] Good Bolting Practice, Volume 1, EPRI Report NP-5067

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[32] AISI Specification for the Design of Cold-Formed Steel Structural Members, 1996 Edition.

[33] Lehigh Testing Laboratories Test No. F-19-32, July 20, 2006

[34] Engineering Change Notice 10580 to Modification EC 1602 (MR 05-017), Revision 0, Dated 4/7/07

[35] Engineering Change Notice 10581 to Modification EC 1602 (MR 05-017), Revision 0, Dated 4/11/07

[36] Engineering Change Notice 10653 to Modification EC 1602 (MR 05-017), Revision 0, Dated 4/19/07

[37] Design Information Transmittal for Point Beach EC 10720, "Thermal Expansion Gap Requirements, Dated 4/27/07

[38] ACI Structural Journal, January-February 1995, VOL. 92 NO. 1
(Included as Attachment J to Calculation PCI-5344-S01)

[39] Point Beach Design Information Transmittal DIT003 for Modification EC 12601 and EC 12603, "Differential Pressure for Debris Interceptors", Dated 8/7/08

ENCLOSURE 5

NEXTERA ENERGY POINT BEACH, LLC
POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
GSI-191/GL 2004-02 (TAC NOS. MC4705/4706)
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

PERFORMANCE CONTRACTING, INC.
CALCULATION TDI-6007-07, REVISION 4, MARCH 10, 2009
VORTEX, AIR INGESTION, & VOID FRACTION
POINT BEACH NUCLEAR PLANT, UNITS 1 & 2

22 pages follow

PCI PERFORMANCE CONTRACTING INC

CALCULATION COVER SHEET

Calculation Number: TDI-6007-07

Technical Document Rev. No. 4 Addenda No.: N/A

Calculation Title: **Vortex, Air Ingestion & Void Fraction – Point Beach Nuclear Plant – Unit - 1 & 2**

Safety Related? **YES**

Calculation Verification Method (Check One):

☒ Design Review ☐ Alternate Calculation ☐ Qualification Testing

Scope of Revision:

Specific revision to address operating temperature range for voiding and updated air Ingestion and Froude calculations. Revision 4, Pages: All

Documentation of Reviews and Approvals:

Originated By: [redacted] Date 3/6/09

Verified By: [redacted] Date March 6 - 2009

Approved By: [redacted] Date 3/10/09

CALCULATION VERIFICATION CHECKLIST

Calculation Title: Vortex, Air Ingestion & Void Fraction – Point Beach Nuclear Plant – Unit – 1 & 2

Revision: 4

	CHECKLIST	Yes	No	n/a
1.	Were inputs correctly selected and incorporated?	☒	☐	☐
2.	Are assumptions adequately described and reasonable?	☒	☐	☐
3.	Are the appropriate quality and quality assurance requirements specified?	☒	☐	☐
4.	Are the applicable codes, standards and regulatory requirements identified and met?	☒	☐	☐
5.	Have applicable construction and operating experience been considered?	☒	☐	☐
6.	Have the design interface requirements been satisfied?	☒	☐	☐
7.	Was an appropriate design method used?	☒	☐	☐
8.	Is the output reasonable compared to input?	☒	☐	☐
9.	Are specified parts, equipment, and processes suitable for the required application?	☐	☐	☒
10.	Are the specified materials compatible with design environmental conditions?	☐	☐	☒
11.	Have adequate maintenance features and requirements been specified?	☐	☐	☒
12.	Are accessibility and other design provision adequate?	☐	☐	☒
13.	Has adequate accessibility been provided to perform the in-service inspection?	☐	☐	☒
14.	Has the design properly considered radiation exposure?	☐	☐	☒
15.	Are the acceptance criteria incorporated in the design documents sufficient to allow verification?	☒	☐	☐
16.	Have adequate pre-operational and subsequent periodic test requirements been specified?	☐	☐	☒
17.	Are adequate handling storage, cleaning and shipping requirements specified?	☐	☐	☒
18.	Are adequate identification requirements specified?	☐	☐	☒
19.	Are requirements for record preparation, review, approval, retention, etc., adequately specified?	☐	☐	☒
20.	Has the appropriate Calculation Guideline Verification Checklist been reviewed and signed?	☒	☐	☐

Note: This is PCI form 3060-3 Revision 3

Verified by/Date: [redacted] 3/6/09 **Initials:** [redacted]

TABLE OF CONTENTS

Originated By: [redacted] **Date** 3/6/09

1.0 Purpose and Summary Results

The US Nuclear Regulatory Commission (USNRC) in generic safety issue (GSI)-191 identified it was possible that debris in PWR containments could be transported to the emergency core cooling system (ECCS) sump(s) following a main steam line break (MSLB) and/or a loss of coolant accident (LOCA). It was further determined that the transported debris could possibly clog the sump screens/strainers and impair the flow of water, thus directly affecting the resultant operability of the various ECCS pumps and the containment spray (CS) system pumps, and their ability to meet their design basis function(s). In order to address and resolve the various issues identified by the USNRC in GSI-191, utilities have implemented a program of replacing the existing ECCS sump screens or strainers with new and improved designs.

In order to address and resolve the specific issues associated with USNRC GSI-191 for the Point Beach Nuclear Plant – Unit 1 & 2 (PBNP-1/2), Point Beach entered into a contract with Performance Contracting, Inc. (PCI). The primary objective of the contract was for PCI to provide a qualified Sure-Flow® Suction Strainer that has been specifically designed for PBNP-1/2 in order to address and resolve the NRC GSI-191 ECCS sump clogging issue.

PCI has prepared a Qualification Report specifically for the subject strainer. The Qualification Report is a compilation of the various documents and calculations that support the strainer qualification. It also provides a "single-source" historical record that can be utilized to address any PBNP-1/2 organizational or NRC regulatory issues or questions associated with the replacement PCI Sure-Flow® Suction Strainer.

As part of the PBNP-1/2 Qualification Report, PCI has performed a number of hydraulic calculations in support of the replacement Sure-Flow® Suction Strainer. This calculation TDI-6007-07, *Vortex, Air Ingestion & Void Fraction – Point Beach Nuclear Plant – Unit – 1 & 2* is one of a number of hydraulic calculations that specifically supports the design and qualification of the subject strainer.

This calculation addresses the various issues associated with the separate but related issues associated with vortex, air ingestion, and void fraction as they relate to the sump and strainer assembly that has been designed specifically for PBNP-1/2.

The PBNP units each have two (2) separate recirculation strainer assemblies that individually and specifically feeds either the 'A' or 'B' train ECCS and CS system. Each of the horizontally oriented recirculation strainer assembly is

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comprised of fourteen (14) modules each made up of ten (10) strainer disks for a total strainer area of 1,904.6 ft^2, or a total of 3,809.2 ft^2 for each pair of strainers associated with one of the PBNP units. Flow leaves the strainers and enters a combination of pipe and fittings before discharging into the containment outlet. PCI drawings **[Drawings 10.1 - 10.9, inclusive]** provide details of the subject configuration.

The results of the calculation are provided in **Table 1.** The calculation utilizes the Acceptance Criteria established in both PBNP-1/2 and USNRC documents with respect to PWR sump performance to specifically evaluate the PBNP-1/2 Sure-Flow® Suction Strainer assembly.

Table 1 – Results Summary

Issue	Acceptance Criteria		Results
	USNRC	PBNP-1/2	
Vortex	No vortex	No detrimental effects on RHR, SI & CS pumps	ACCEPTABLE - Vortex formation is precluded by the PCI Sure-Flow® Suction Strainer design and configuration
Air Ingestion	0% or <2%	No detrimental effects on RHR, SI & CS pumps	ACCEPTABLE – Air ingestion will not occur since there is no vortex formation associated with the PCI Sure-Flow® Suction Strainer design and configuration
Void Fraction	≤3%	N/A	ACCEPTABLE – Voids will not occur at the strainer or before leaving the PCI Sure-Flow® Suction Strainer assembly and discharge piping and entering the PBNP-1/2 containment outlet

It was concluded that this calculation, an integral portion of the Qualification Report completely supports the qualification, installation, and use of the PCI Sure-Flow® Suction Strainer for Point Beach Nuclear Plant – Unit – 1 & 2 without any issues or reservations.

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2.0 Definitions and Terminology

The following Definitions & Terminology are defined and described as they are utilized in this calculation.

Sure-Flow® Suction Strainer – Strainer developed and designed by Performance Contracting, Inc. that employs Surë-Flöw® technology to reduce inlet approach velocity.

Emergency Core Cooling System (ECCS) – The ECCS is a combination of pumps, piping, and heat exchangers that can be combined in various configurations to provide either safety injection or decay heat cooling to the reactor.

Clean Strainer Head Loss (CSHL) – Is the calculated head loss for the Sure-Flow® Suction Strainer based on actual testing performed at the Electric Power Research Institute's (EPRI) Charlotte NDE Center, and Fairbanks Pump Company Hydraulic Laboratory. The later testing did not involve any debris.

Point Beach Nuclear Plant Unit 1 & 2 – also known as Point Beach, PBNP-1/2, and PB-1/2.

~~**Main Steam Line Break** – also known as MSLB. A MSLB is not a LOCA.~~

Containment Spray System – also known as CSS or CS. System is utilized to address either a MSLB or a LOCA.

Loss-Of-Coolant-Accident – also known as a LOCA. A LOCA is the result of a pipe break or inadvertent leak that results in the discharge of primary reactor coolant from the normal nuclear steam supply system (NSSS) boundary. A LOCA can be classified as a large break LOCA (LBLOCA) or a small break LOCA (SBLOCA). Classification is directly dependent upon the nominal size of the affected pipe that is associated with the LOCA.

3.0 Facts and Assumptions

The following Facts (designated as [F]) & Assumptions (designated as [A]) were utilized in the preparation of this calculation.

3.1 A flow velocity of 0.0026 fps would be characteristic of the PBNP-1/2 strainer, through a debris bed consisting of fibers and particulate, is 100% viscous flow. Accordingly, the head loss is linearly proportional to dynamic viscosity [A].

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3.2 A scale strainer, which is designed to maintain the same approach velocity as the full scale production strainer, can accurately simulate the performance of the full scale production strainer so long as the same scaling factor is used for strainer area, water flow rate, and debris quantities. The scaling factor is defined as ratio of the surface area of the scale strainer to the surface area of the full scale production strainer [A].

3.3 The head loss resulting from flow through a fiber – particulate debris bed at the approach velocity for the PBNP-1/2 strainer (0.0026 ft/s) **[Reference 9.6]**, is 100% viscous flow, as opposed to inertial flow. As viscous flow, head loss is linearly dependent on the product of viscosity and velocity. Therefore, to adjust the measured head loss across a debris bed with colder water, a ratio of water viscosities, between the warmer specified post-LOCA water temperature and the colder test temperature, can be multiplied by the measured head loss to obtain a prediction of the head loss with water at the specified post-LOCA temperature [A].

4.0 Design Inputs

The following combination of Point Beach and PCI Design Inputs were utilized in the preparation of this calculation.

4.1 Point Beach Nuclear Plant Specification, Specification No, PB-681, *Replacement of Containment Sump Screens*, Revision 2, February 17, 2006 **[Reference 9.1]**, document provides design input associated with strainer flow rate, water temperature, and the maximum allowable head loss.

4.2 Performance Contracting, Inc. (PCI) Calculation TDI-6007-02, *SFS Surface Area, Flow and Volume Calculation*, Revision 2 **[Reference 9.12]**, document provides relevant dimensions and other information specifically associated with the PBNP-1/2 strainers.

4.3 PCI Calculation TDI-6007-03, *Core Tube Design – Point Beach Nuclear Plant – 1/2*, Revision 0 **[Reference 9.6]**, document provides relevant data with regard to flow rate in the PBNP-1/2 strainer.

4.4 PCI Calculation TDI-6007-05, *Clean Head Loss – Point Beach Nuclear Plant – 1/2*, Revision 4 **[Reference 9.7]**, document provides the head loss associated with the "clean" PBNP-1/2 strainer and attached pipe and fittings.

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4.5 PCI Calculation TDI-6007-06, *Total Head Loss – Point Beach Nuclear Plant – 1/2*, Revision 5 **[Reference 9.16]**, document provides the total head loss associated with the PBNP-1/2 strainer and attached pipe and fittings.

4.6 Point Beach Nuclear Plant, NPL 2009-0027 - Design Information Transmittal in Support of Calculation TDI-6007-07 Rev. 4, dated February 13, 2009 **[Reference 9.17]**, document provides pressure information for addressing voiding in the Point Beach strainer suction lines.

5.0 Methodology

PCI utilized classical hydraulic calculations (conventional calculation methodology) to address the subject issues. PCI recognizes that if it is determined that one of the issues cannot occur and/or can be prevented, then one or more of the other issues cannot occur (e.g., if a vortex is not predicted by calculation then there should be no air ingestion). However, PCI has conservatively assumed that each issue is separate, and each issue will be addressed on its own merits.

6.0 Acceptance Criteria

This specific calculation addresses three (3) separate but related issues – vortex, air ingestion and void fraction. Accordingly, each issue has it own separate acceptance criterion. The final overall acceptance criterion is that the PBNP-1/2 ECCS pumps have adequate NPSH margin under all postulated post-LOCA conditions.

Vortex

The USNRC in RG 1.82 Revision 3 **[Reference 9.4]** has indicated that air ingestion can lead to ECCS pump degradation and/or failure. A vortex is a potential source of air ingestion. A vortex can be prevented due to various combinations of sump configuration and the addition of vortex suppressors in the sump.

The Acceptance Criteria for vortex is the complete elimination of occurrence.

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Air Ingestion

RG 1.82 Revision 3 **[Reference 9.4]** states that air ingestion can lead to ECCS pump degradation and/or failure if air ingestion is > 3%. Accordingly, the USNRC has recommended a limit of 2% by volume limit on sump air ingestion. In addition, the USNRC has also recommended that even with air ingestion levels at 2% or less, NPSH can still be affected. The USNRC has further recommended that if air ingestion is indicated, that the NPSH be corrected from the pump curves.

The Acceptance Criteria for air ingestion is ≤ 2%.

Void Fraction

USNRC GSI-191 Safety Evaluation (SE) **[Reference 9.3]** has indicated that ECCS pumps can experience cavitation problems when inlet void fraction exceeds approximately 3%.

The Acceptance Criteria for void fraction is ≤3% in conjunction with an acceptable sump pool temperature operating range as specified in Attachment V-1 of **[Reference 9.5]**.

7.0 Calculation(s)

In order to address and determine the acceptability and/or issues potentially associated with the three (3) separate but related issues of vortex, air ingestion and void fraction, a separate analysis of each issue was performed.

7.1 Vortex

The PBNP-1/2 specification **[Reference 9.1]**, specifically sections 3.6.12 and 4.1 address strainer vortex, but do not provide limitations on the new strainer design that specifically prohibits the formation of a vortex (i.e., no vortex allowed). Accordingly, PCI has utilized the guidance of USNRC RG 1.82, Revision 3 **[Reference 9.4]** to address the vortex issue for the PBNP-1/2 strainers.

In **[Reference 9.4]**, the USNRC provided generic guidance with respect to PWR sump performance, sump design, and vortex suppression. The subject reference can be utilized as a means of assessing sump hydraulic performance, specifically the issues associated with a potential vortex in the sump.

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PBNP-1/2 does not have a sump that collects post-LOCA water to support ECCS and CS functions. Instead, the PBNP-1/2 utilizes two (2) containment outlet penetrations located in the floor of the containment that are "covered" by a vertical oval cross-section structure. The structure consists of an outer "coarse" screen (composed of a combination of 24" OD by ½" wall pipe and ½" plate) with slotted openings to facilitate post-LOCA water flow to the pumps. Inside of this structure are two (2) vertical "fine" screen cylinders (one for each containment outlet) that are 13-1/2" ID. The "fine" screen cylinders preclude smaller particles and debris from entering the pumps **[Reference 9.8 – 9.10, inclusive]**.

Since the PBNP-1/2 containment outlet structure is being modified by the addition of the PCI Sure-Flow® suction strainer, the guidance offered by the USNRC in **[Reference 9.4]** is not entirely or specifically applicable. However, the guidance does provide some information that can be utilized in the assessment of the PBNP-1/2 strainer configuration with regard to vortex issues.

The "revised" PBNP-1/2 strainer configuration will utilize a pair of horizontally oriented, PCI Sure-Flow® suction strainers each consisting of eleven (11) strainer modules. The flow from the strainers discharges through attached pipe and fittings to the existing containment outlet located in the containment floor. The subject strainer discharge pipe will take the place of the existing containment outlet structure **[Drawings 10.1 – 10.9, inclusive]**.

The PCI Sure-Flow® suction strainer will be analyzed and addressed with respect to vortex issues.

PCI Sure-Flow® Suction Strainer JJE

The PCI Sure-Flow® suction strainer for PBNP-1/2 is comprised of ~~eleven (11)~~ fourteen (14) horizontally oriented modules each containing ten (10) disks. The disks are a nominal 5/8" thick and are separated 1" from each adjacent disk. The interior of the disks contain rectangular wire stiffeners for support, configured as a "sandwich" made up of three (3) layers of wires - 7 gauge, 8 gauge, and 7 gauge. The disks are completely covered with perforated plate having 0.066" holes. The end disk of a module is separated approximately 5" from the end disk of the adjacent module. The 5" space between adjacent modules is covered with a solid sheet

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metal "collar." Each of the modules has cross-bracing on the two exterior vertical surfaces of each module.

Based on the design configuration of the PBNP-1/2 strainer assembly, the largest opening for water to enter into the sump is through the perforated plate 0.066" holes. The size of the perforated plate holes by themselves would preclude the formation of a vortex. However, in the unlikely event that a series of "mini-vortices" combined in the interior of a disk to form a vortex, the combination of the wire stiffener "sandwich" and the small openings and passages that direct the flow of water to the strainer core tube would further preclude the formation of a vortex in either the core tube or the sump.

The USNRC in **[Reference 9.4]**, specifically Table A-6 guidance is provided with regard to vortex suppressors. The table specifies that standard 1.5" or deeper floor grating or its equivalent has the capability to suppress the formation of a vortex with at least 6" of submergence.

The design configuration of the PCI Sure-Flow® suction strainer for PBNP-1/2 due to the close spacing of various strainer components and the small hole size of the perforated plate meets and/or exceeds the guidance found in Table A-6. The PBNP-1/2 strainer does not meet the 6" submergence requirement. The configuration for PBNP-1/2 results in only 2" of submergence to the top of the strainer assembly. However, there is a submergence level of approximately 10.5" of submergence to the top of the core tube. In addition the water flow would have to pass through more than 8" of combined perforated plate, wire stiffener "sandwiches", and cross-bracing which would further preclude the formation of a vortex.

The USNRC carried out a number of tests regarding vortex suppressors at the Alden Research Laboratory (ARL) to arrive at the information summarized in Table A-6 of **[Reference 9.4]**. The PCI Sure-Flow® suction strainer prototype for PBNP-1/2 was also tested at ARL under various conditions. During the testing of the PBNP-1/2 prototype strainer even when partially uncovered, did not exhibit any characteristics associated with a vortex or vortex development. Also, test observations of the minimum water level above a full size PBNP-1/2 strainer module showed no evidence of vortexing during testing **[Reference 9.18]**.

It can therefore be concluded that the configuration of the PBNP-1/2 Sure-Flow® suction strainer will prevent the formation of vortex development.

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7.2 Air Ingestion

The PBNP-1/2 specification **[Reference 9.1]**, specifically section 3.6.17 addresses air ingestion, but does not provide limitations on the new strainer design that limits air ingestion to a specific value (i.e., <2%). Accordingly, PCI has utilized the guidance of USNRC RG 1.82, Revision 3 **[Reference 9.4]** to address air ingestion for the PBNP-1/2 strainers. Appendix A and Table A-1 of **[Reference 9.4]** indicate that sump performance specifically related to air ingestion is a strong function of the Froude Number, Fr. By limiting the Froude Number to a maximum of 0.25, air ingestion can be maintained to <2%.

The flow of post-LOCA water from a piping system associated with a LBLOCA or SBLOCA, or a CS initiation associated with a MSLB or LOCA collects in the lower areas of the containment and eventually migrates to the ECCS sump. For the purposes of calculation, flow can be considered classified as open channel flow. For open channel flow, the Froude Number, **Fr**, is defined as the ratio between the force of inertia and the gravitational force **[Reference 9.13]**. This can be expressed as follows:

Equation 1 $$Fr = V / (g \times L)^{1/2}$$

Where **V** = the velocity of water through a core tube slot,
For PBNP-1/2 V_{ex} = 3.478 ft/s **[Reference 9.6]**,

L = the characteristic length L can be replaced by the hydraulic depth D defined as the ration of the cross-sectional area of the core tube divided by the width of the free surface (or the circumferential slot width for the core tube hole velocity),

g = gravitational constant, 32.2 ft/s^2.

The most conservative value that can be utilized for **D** is the case of the ratio of core tube cross-sectional area to the slot width for the first hole at the core tube exit, using the hole velocity calculated in **Reference 9.6**.

From the PBNP-1/2 Clean Head Loss report **[Reference 9.7]**, A_{ex} = 1.344 ft^2. The PBNP-1/2 Core Tube Design report **[Reference 9.6]** was used in **Drawing 10.10** to calculated a slot width of 0.30 in, or 0.025 ft, for the hole velocity of 3.4409. Therefore, the ratio of the core tube area to the circumferential slot width can be calculated as follows:

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$$D = (1.344 / 0.025)$$

$$= 53.76 \text{ ft}$$

Accordingly, value of **Fr** can be calculated as follows.

$$Fr = V / (g \times D)^{1/2}$$

$$Fr = 3.4409 / (32.2 \times 53.76)^{1/2}$$

$$= 3.4409 / 41.6061$$

$$= 0.0827$$

The calculated Froude Number for the PBNP-1/2 PCI Sure-Flow® suction strainer is approximately 67% lower than the USNRC guidance found in **[Reference 9.4]** of 0.25. The Froude Number decreases to 0.031 at the end of the strainer. Therefore due to the combination of a low Froude Number and lack of an air entrainment mechanism (i.e., vortex formation) in conjunction with the complete submergence of the strainer, air ingestion is not expected to occur.

It can therefore be concluded that the PBNP-1/2 strainers will have air ingestion of <2%.

7.3 Void Fraction

The PBNP-1/2 specification **[Reference 9.1]**, does not specifically address the issue of Void Fraction. It must be shown that flashing (i.e., voiding) does not occur anywhere within the strainer assembly throughout the operating sump temperature range. To demonstrate this, flashing will be evaluated across the screen itself and at the strainer assembly outlet. It must also be shown that adequate pressure remains available at the outlet of the strainer assembly to prevent flashing in the downstream SI-850 valve **[Reference 9.17]**.

The pressure available to prevent flashing throughout the strainer assembly is the sum of the containment pressure and the pressure due to the sump water level less the dynamic losses. To prevent flashing, the pressure available must exceed the vapor pressure of the sump water **[Reference 9.17]**.

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Accordingly, PCI has utilized the guidance of **[Reference 9.2 and 9.15]** to address the void fraction issue for the PBNP-1/2 strainers.

Although it is asserted in various regulatory documents that void formation is directly related to air ingestion, this is not correct. Void formation is the result of the pressure of a fluid being reduced below the saturation pressure with the resulting voids being formed by the flashing of the liquid phase. Air does not need to be present to create significant voiding.

PCI has evaluated the issue of Void Fraction for PBNP-1/2 by the use of the following information provided by Point Beach **[Reference 9.17]** as input to hydraulic and fluid flow calculations to determine the PBNP-1/2 Void Fraction.

Calculation Methodology

7.3.1 Evaluation of Flashing across the Strainer Screen [Reference 9.17]

Pressure Available at Screen > Vapor Pressure

$\Rightarrow P_{Air} + P_{Vapor} + P_{Submergence} - P_{Velocity} - \Delta P_{Strainer} > P_{Vapor}$, then

$\Rightarrow \Delta P_{Strainer} < P_{Air} + P_{Submergence} - P_{Velocity}$

Where,

P_{Air}	≈ 12.7 psia	(14.7 -2.0 psig) is the minimum containment air pressure allowed [PBNP TS 3.6.4],
$P_{Submergence}$	≈ 0 psi	Negligible since the minimum initial sump level provides 2" of submergence at the top of the strainer screens [PCI Drawings SFS-PB1-GA-00 & SFS-PB2-GA-00], and
$P_{Velocity}$	≈ 0 psi	Negligible since a flow velocity of 0.0026 fps is expected through the debris bed [PCI Calculation TDI-6007-06 Rev. 5]. A similarly small velocity is expected across the screens, then

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$\Delta P_{Strainer}$	= 12.7 psid	The maximum allowable pressure loss across the debris loaded screens to prevent flashing across the screen debris bed.

PBNP-1/2 **[Reference 9.1]** defined the containment post-LOCA water temperature as being 212° F. The total debris laden head loss was 3.474 feet of water **[Reference 9.16]**, based on the 212° F water. Converting 3.474 feet of water equates to 1.44 psi.

The PBNP evaluation for strainer debris loaded differential pressure shows a maximum allowable of 12.7 psid. The 1.44 psi calculated by PCI for the head loss across the strainer is less than 12% of the PBNP evaluated allowable differential pressure. Therefore no voiding across the strainer debris bed is expected.

7.3.2 Evaluation of Flashing at the Strainer Assembly Outlet

Pressure Available at Assembly Outlet > Vapor Pressure

$\Rightarrow P_{Air} + P_{Vapor} + P_{Submergence} - P_{Velocity} - \Delta P_{Strainer} > P_{Vapor}$, then

$\Rightarrow \Delta P_{Strainer} < P_{Air} + P_{Submergence} - P_{Velocity}$

Where,

P_{Air}	= 12.7 psia	The minimum containment air pressure allowed (14.7-2.0 psig) [TS 3.6.4].
$P_{Submergence}$	= 1.3 psi	which is the minimum initial sump level provided by 38" of submergence at the strainer assembly outlet [PCI Drawings SFS-PB1-GA-00 & SFS-PB2-GA-00]. and
$P_{Velocity}$	= 0.1 psia	the dynamic velocity head ($V^2/2g$) at 2200 gpm, velocity in the 18" elbow is less than 3.6 fps [Crane 410Page B-14 and Eq. 1-3]. then
$\Delta P_{Strainer}$	= 13.9 psid	is the maximum allowable pressure loss across the entire strainer assembly to ensure flashing does not occur at the assembly outlet.

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Therefore, to assure that flashing does not occur at the strainer assembly outlet, the total head loss across the strainer assembly must be less than **13.9 psid** throughout the operating sump temperature range.

The PBNP evaluation for strainer debris loaded differential pressure shows a maximum allowable of 13.9 psid. The 1.44 psi calculated by PCI for the head loss across the strainer at 212°F is less than 10.5% of the PBNP evaluated allowable differential pressure. Therefore no voiding across the strainer debris bed is expected.

7.3.3 Evaluation of Flashing near the Assembly Outlet with SI-850 Valve

Pressure Available at Assembly Outlet >Pressure Required to prevent SI-850 Flashing

$\Rightarrow P_{Air} + P_{Vapor} + P_{Submergence} - P_{Velocity} - \Delta P_{Strainer} > P_{SI\text{-}850} - (P_{Vapor\,@212F} - P_{Vapor})$, then,

$\Rightarrow \Delta P_{Strainer} < P_{Air} + P_{Submergence} - P_{Velocity} - P_{SI\text{-}850} + P_{Vapor\,@\,212F}$

Where,

P_{Air}	= 12.7 psia	is the minimum containment air pressure allowed (14.7-2.0 psig) [TS 3.6.4],
$P_{Submergence}$	= 1.3 psi	which is the minimum initial sump level provided by 38" of submergence at the strainer assembly outlet [PCI Drawings SFS-PB1-GA-00 & SFS-PB2-GA-00],
$P_{Velocity}$	= 0.1 psia	the velocity head ($V^2/2g$) at 2200 gpm, velocity in the 18" elbow is less than 3.6 fps [Crane 410 Page B-14 and Eq. 1-3],
$P_{SI\text{-}850}$	= 20.9 psia	which is 4.2 psig as required at the SI-850 valve assembly at 212 °F to prevent flashing [PBNP Calc N-92-086 Rev. 4], and to assure no flashing, 2 psi is added to the predicted value [SER 2006-0003, PBNP Calc N-92-086 Rev. 4], and

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$P_{Vapor @ 212F}$	= 14.7 psia	A sump water vapor pressure of 212 °F is required to account for temperature dependent changes in SI-850 flash suppression pressure requirements and the vapor pressure, then
$\Delta P_{Strainer}$	= 7.7 psid	is the maximum allowable pressure loss across the entire strainer assembly to ensure flashing does not occur in the SI-850 valve assembly.

Point Beach further adds that a downstream valve in the strainer suction pathway **[References 9.13 and 9.17]** may cause additional flashing due to resistance and dynamic pressure changes in the valve. To address flashing at the valve (SI-850), a total head loss across the strainer must not exceed 7.7 psid throughout the operating sump temperature range. **Table 2** has been generated to document the strainer head loss performance against the varying temperature dependent voiding limits.

Table 2 – Flashing Margin For Operating Temperature Range.

°F	Total Corrected Head Loss (ft) [Reference 9.16]	Density ρ (lb/ft^3)	psi Equivalent	Flashing Margin (7.7 psid Allowable)
212	3.47	59.83	1.44	6.26
192	3.93	60.31	1.64	6.06
172	4.43	60.75	1.87	5.83
152	5.08	61.16	2.16	5.54
132	5.93	61.52	2.53	5.17
112	7.07	61.83	3.03	4.67
92	8.64	62.09	3.72	3.98
72	10.93	62.29	4.73	2.97
52	14.42	62.41	6.25	1.45
32	20.22	62.42	8.76	***-1.06***

Based on the temperature range data presented in **Table 2**, head loss in the PCI strainers should not allow flashing anywhere within the strainer assembly or in the SI-850 valve throughout the operating range until temperature is reduced below 52 °F.

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8.0 Conclusions

The result of this calculation, specifically the acceptability of the issues associated with vortex, air ingestion, and void fraction are summarized in **Table 3.**

It was concluded that the subject issues have been addressed for PBNP-1/2 and the results indicate that there are no vortex, air ingestion or void fraction issues with the installation of the PCI Sure-Flow® Suction Strainers. This specific calculation completely supports the qualification, installation, and use of the PCI Sure-Flow® Suction Strainer for Point Beach Nuclear Plant – Unit 1 & 2 without any issues or reservations.

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Table 3 – Calculation Results

Issue	Acceptance Criteria		Results	Comments
	USNRC	PBNP-1/2		
Vortex	None (Ref: RG 1.82, Rev. 3)	N/A No detrimental effects on RHR, SI & CS pumps	**ACCEPTABLE** No Vortex – vortex formation is *precluded* by the PCI Sure-Flow® Suction Strainer design and configuration	Results applicable to the PBNP-1/2 Sure-Flow® strainer.
Air Ingestion	0% or <2% (Ref: RG 1.82, Rev. 3)	No detrimental effects on RHR, SI & CS pumps	**ACCEPTABLE** Air Ingestion could occur – calculation indicates > 0% but < 2%. However, since it has been determined that vortex formation will not occur then it can be reasonably concluded that air ingestion will also not occur.	Per RG 1.82, Revision 3, if air ingestion is > 0%, the pump NPSH must be corrected by the relationship, $NPSH_{required\ (\alpha p<2\%)} = NPSH_{required(liquid)} \times \beta$, where $\beta = 1 + 0.50\alpha_p$ and α_p is the air ingestion rate (in percent by volume) at the pump inlet flange.
Void Fraction	≤3% (Ref: USNRC GSI-191 Safety Evaluation (SE))	N/A	**ACCEPTABLE** Void Fraction will not occur at the strainer – calculation indicates 0%. Additionally, the calculation also concludes that voids will not occur in the SI-850 valve with temperature decreasing throughout the operating range.	Conventional calculation methodology indicates that no void fraction will occur at the *strainer*. The pressure is sufficient to prevent voiding at the SI-850 valve through 52 °F. Cavitation at the valve assembly may occur at colder temperatures for design flow conditions.

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9.0 References

9.1 Point Beach Nuclear Plant Specification, Specification No, PB-681, *Replacement of Containment Sump Screens,* Revision 1, August 25, 2005

9.2 Information Systems Laboratories (ISL), Inc., Report ISL-NSAD-TR-05-01, *Development and Implementation of an Algorithm for Void Fraction Calculation in the "6224 Correlation" Software Package*, January 2005, prepared for the USNRC

9.3 U.S. Nuclear Regulatory Commission, Safety Evaluation, *Pressurized Water Reactor Sump Performance Evaluation Methodology*, Guidance Report of the Nuclear Energy Institute (NEI), GSI-191 SE, Revision 0, dated December 6, 2004

9.4 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.82, *Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident*, Revision 3, dated November 2003

9.5 U.S. Nuclear Regulatory Commission, GSI-191 SE, *Attachment V-1, NUREG/CR-6224 Head Loss Temperature Assessment.* Revision 0, December 2004

9.6 Performance Contracting, Inc. (PCI), Technical Document Number, TDI-6007-03, *Core Tube Design – Point Beach Nuclear Plant – Unit 1/2*, Revision 0

9.7 Performance Contracting, Inc. (PCI), Technical Document Number, TDI-6007-05, *Clean Head Loss – Point Beach Nuclear Plant – Unit 1/2*, Revision 4

9.8 Bechtel, Job No. 6118, Drawing No. M-276, Revision 2, Point Beach Nuclear Plant Unit 1 & 2, *Containment Safety Injection Sump Requirements for Screens*

9.9 Bechtel, Job No. 6118, Drawing No. C-126, Revision 7, Point Beach Nuclear Plant Unit 1 & 2, *Liner Plate – Floor Plan*

9.10 Bechtel, Job No. 6118, Drawing No. C-128, Revision 9, Point Beach Nuclear Plant Unit 1 & 2, *Containment Structure Interior Plans at El. 10'-0, El. 21'-0, El. 24'-8 & 38'-0*

Originated By: [redacted] **Date** 3/6/09

9.11 Not Used

9.12 PCI, Technical Document Number, TDI-6007-02, *SFS Surface Area, Flow and Volume Calculation*, Revision 2

9.13 Nazeer, Ahmed, *Fluid Mechanics*, Engineering Press, Inc., 1987

9.14 Not Used

9.15 USNRC, *6224 Correlation*, publicly available software

9.16 PCI Calculation TDI-6007-06, *Total Head Loss – Point Beach Nuclear Plant – 1/2*, Revision 5

9.17 Point Beach Nuclear Plant, NPL 2009-0027 - Design Information Transmittal in Support of Calculation TDI-6007-07 Rev. 4, dated February 13, 2009

9.18 EC-PCI-PB-6028-1001, AREVA Document No. 66-9093957-002, Point Beach Test Report for ECCS Strainer Performance Testing. Dated 11/26/2008

Originated By: [redacted] Date 3/6/09

10.0 Drawings

10.1 SFS-PB1-GA-00, Revision 6, Point Beach Unit 1, *Sure-Flow® Strainer, Recirc Sump System*

10.2 SFS-PB1-GA-02, Revision 6, Point Beach Unit 1, *Sure-Flow® Strainer, A Strainer*

10.3 SFS-PB1-GA-04, Revision 5, Point Beach Unit 1, *Sure-Flow® Strainer, Piping A Layout*

10.4 SFS-PB1-GA-05, Revision 9, Point Beach Unit 1, *Sure-Flow® Strainer, Piping B Layout*

10.5 SFS-PB1-PA-7100, Revision 2, Point Beach Unit 1, *Sure-Flow® Strainer, Module Assembly*

10.6 SFS-PB2-GA-00, Revision 2, Point Beach Unit 2, *Sure-Flow® Strainer, Recirc Sump System*

10.7 SFS-PB2-GA-02, Revision 9, Point Beach Unit 2, *Sure-Flow® Strainer, A Strainer*

10.8 SFS-PB2-GA-04, Revision 5, Point Beach Unit 2, *Sure-Flow® Strainer, Piping Assembly Layout*

10.9 SFS-PB2-PA-7100, Revision 1, Point Beach Unit 2, *Sure-Flow® Strainer, Module Assembly*

Originated By: [redacted] **Date** 3/6/09

ENCLOSURE 6

NEXTERA ENERGY POINT BEACH, LLC
POINT BEACH NUCLEAR PLANT, UNITS 1 AND 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
GSI-191/GL 2004-02 (TAC NOS. MC4705/4706)
POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED WATER REACTORS

AREVA CALCULATION 51-9056525, REVISION 001, 4/28/2008.
CHEMICAL PRECIPITATION ANALYSIS FOR POINT BEACH NUCLEAR PLANT USING WCAP-16530-NP

45 pages follow

AREVA

March 16, 2009
AREVA-09-01215

Tom Kendall, PE
Sr. Technical Advisor
Design Engineering
Point Beach Nuclear Plant

Mr. Kendall,

AREVA performed GSI-191 Chemical Effects Calculations for Point Beach Nuclear Plant. The deliverables were AREVA Engineering Information Record (EIR), document numbers: 51-9010780-001 and 51-9056525-001. These documents were incorrectly stamped as proprietary.

No AREVA intellectual rights or trade secret were found after completing the review of these documents. Therefore, these documents can be status as non-proprietary for use by Point Beach Nuclear Plant.

Please feel free to contact me if you have any questions or requests regarding this matter.

Sincerely,

Ray Phan
Manager 1
BOP System Engineering
Office: 704-805-2231
Mobile: 704-575-8924

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AREVA

ENGINEERING INFORMATION RECORD

Document Identifier 51 - 9056525 - 001

Title Chemical Precipitation Analysis for Point Beach Nuclear Plant Using WCAP-16530-NP

PREPARED BY:	REVIEWED BY:
NAME H. Dergel	NAME R. Jetton
Signature [signature] Date 9/27/07	Signature Rebecca Jetton Date 9/27/07

Technical Manager Statement: Initials BI

Reviewer is Independent.

Remarks:

The purpose of this document is to determine the type(s) and bounding quantities of chemical precipitates expected to form in the containment sump pool following a Design Basis Loss-of-Coolant-Accident (LOCA), when generated debris or other susceptible materials may be subject to acid or caustic fluids. This evaluation has been performed based upon plant-specific design parameters primarily using the guidance published within WCAP-16530-NP and the associated Chemical Model Spreadsheet. Sensitivity analyses were performed to investigate the effects of varying design input parameters, as well as applying specific reduction tactics directed within WCAP-16785-P.

This evaluation is required to understand the evolution of the chemical environment present inside the Unit 1 and 2 Point Beach Nuclear Plant (PBNP) reactor containment and containment sump pools following a LOCA. The results of this evaluation may be used as inputs into the downstream effects evaluation or as chemical debris mixture inputs into sump strainer qualification testing for Point Beach, as results are used to direct the generation and subsequent introduction of chemical debris. This is a safety related evaluation.

AREVA

ENGINEERING INFORMATION RECORD

Document Identifier 51 - 9056525 - 001

Title Chemical Precipitation Analysis for Point Beach Nuclear Plant Using WCAP-16530-NP

PREPARED BY:		REVIEWED BY:	
NAME [redacted]		NAME [redacted]	
Signature [redacted]	Date 9/27/07	Signature [redacted]	Date 9/27/07

Technical Manager Statement: Initials [redacted]

Reviewer is Independent.

Remarks:

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This evaluation is required to understand the evolution of the chemical environment present inside the Unit 1 and 2 Point Beach Nuclear Plant (PBNP) reactor containment and containment sump pools following a LOCA. The results of this evaluation may be used as inputs into the downstream effects evaluation or as chemical debris mixture inputs into sump strainer qualification testing for Point Beach, as results are used to direct the generation and subsequent introduction of chemical debris. This is a safety related evaluation.

DOWNGRADED TO NON-PROPRIETARY BY AREVA CORRESPONDENCE #AREVA-09-01215 DATED MARCH 16, 2009

NMC Committed to Nuclear Excellence Fleet Modification Process	**Design Review Comment Form**

Sheet 1 of 1

DOCUMENT NUMBER/ TITLE: Calc 51-9056525

REVISION: 001 DATE: 9/27/2007

REVIEWER'S COMMENTS

This calculation revision (-001) is a result of an error found during the owner's acceptance review of revision -000. The error was a transcription problem in the table of the final results (table 6-1). While correcting the original revision, enhancements were also incorporated into the portrayal of the various cases considered (table 5-1 was the result), and in tabulating the equivalent concentrations in table 6-1.

This calculation has been reviewed and found to be correct in the following respects:

1) A sampling of the results have been corroborated by an independent check by the Owner's Reviewer by running the same spread sheet model, and

2) The inputs have been verified to be correct per the verified inputs provided to AREVA.

However, the calculation results must be applied judiciously, and with a thorough understanding of their derivation and the underlying assumptions.

This calculation does not calculate one single credible "worst case" scenario for the Point Beach units. Rather, it uses a matrix approach to illustrate sensitivities, and to explore the bounding envelope of potential chemical effects outcomes. Specific cautions for future users are itemized below.

1. Cases 1.1, 1.2, 2.1, and 2.2 should ***not*** be used as design bases inputs. These cases each assume that there is no sump mixing, even after sump recirculation is initiated. This is an unrealistic assumption, and is not widely used in industry. The utility of these cases is to establish the differences in chemical generation between maximum sump levels (cases 1.1 and 2.1) and minimum sump levels (cases 1.2 and 2.2). Based on those results, it is clear that using a maximum sump level assumption will result in the maximum (bounding) quantity of chemical precipitant generation. All subsequent cases use an assumption of maximum sump level with a mixed sump.
2. Cases 1.6 and 2.6 should ***not*** be used as design bases inputs without substantial additional work. These cases credited the inhibition of aluminum corrosion due to the presence of silica in the sump water. While this may be a valid mechanism for inhibiting aluminum corrosion, it would first be necessary to ensure that *all* such breaks *will* result in sufficient silica to effectively inhibit the corrosion. Since this has not been done, use of the results from these runs is not appropriate.
3. Cases 1.1-1.6 and 2.1-2.6 use a "worst of the worst" method for determining chemical contributors from the various debris sources. These are unit specific, and can be considered the bounding chemical inputs. After eliminating cases 1.1, 1.2, 2.1, 2.2, 1.6, and 2.6 from consideration (see above), case 2.5 can be seen as the most limiting. Therefore, this case should be considered the limiting **design basis case.** It is important to recognize that this is a contrived case that assumes a contrived case that assumes a less-than-maximum-sized LOCA. This is evidenced by the prolonged duration of containment spray on injection. LOCAs smaller than this would not likely result in the actuation of containment spray, or in the securing of containment spray earlier in the event due to not having severe core damage or high containment pressure.
4. When using table 6-1, care should be taken to **not use the concentrations listed.** These concentrations were derived using the maximum sump volume to establish the total mass, but then divided that mass of chemical precipitants by the mass in the minimum sump volume (this approach is noted at the bottom of the page). This produces an erroneous and excessively high chemical concentration. If chemical concentrations are desired, then they must be calculated from the chemical masses listed in the table and then divided by the mass of the maximum sump level. Both can be obtained from within the calculation.
5. Appendices N.1 and N.2 are break-specific runs that were used to assess whether application of the silica inhibition of aluminum corrosion could be credited. In all cases considered, it appears that silica

concentrations would be sufficiently high to invoke the WCAP guidance on silica inhibition. However, the evaluation did not consider all potential break locations. Additionally, silica inhibition effects were found to be minimal because most of the corrosion occurs during injection spray when there is no silica in the spray water. Therefore, as noted in #2 above, these runs do not provide a significant benefit, and have not been shown to be bounding.

6. Electronic files of the input spreadsheets used for this calculation were part of the deliverables to PBNP from AREVA. After consideration of the delivered calculation, it was determined that additional information was desired. Specifically, the site needs to be able to demonstrate that replacing existing asbestos insulation with other types of insulation is acceptable, and that the chemical effects of such replacements are known and bounded by this analysis.

As noted in OAR comment #3 above, case 2.5 is the most limiting credible condition. Therefore, the spreadsheet for case 2.5 was altered into 3 supplemental cases:

2.5.1: Replace all asbestos with CalSil

2.5.2: Replace all asbestos with generic fiberglass

2.5.3: Replace all asbestos with NUKON

These runs were independently prepared and verified by qualified site personnel (signatures at the bottom of this form), and the inputs and results are attached to the vendor prepared calculation.

The results of the runs show that while the total amount of precipitate can increase due to insulation replacements, the effect is very small, even if 100% of the asbestos is replaced. The following table summarizes the results of the supplemental runs, and should be used when considering appropriate qualification testing:

Case #	Total Ppt Mass (kg)	Total Al Mass (kg)	[Al] at max sump lvl (ppm)
2.5	194.119	19.97	16.3
2.5.1	194.119	19.98	16.3
2.5.2	196.599	20.23	16.5
2.5.3	195.964	20.17	16.5

Reviewer: [redacted]	Date: 4-28-08	Preparer: [redacted]	Date: 4/28/08

(CASE 2.5.1, 2.5.2, + 2.5.3 ONLY)

Multiple Preparer/Reviewer Signature Block

Name (printed)	Signature	P/R	Date	Pages/Sections Prepared or Reviewed

Note: P/R designates Preparer (P) or Reviewer (R).

Record of Revisions

Revision	Date	Pages/Sections Changed	Brief Description
0	8/24/2007	All	Initial Issue
1	9/27/2007	All	The following changes were made in this revision: 1) Revisions to all Tables 2) Revisions to all Sections to clarify report text 3) Changes to pH inputs for Cases 1.4 and 2.4 (Appendices E & K). 4) Changes in Appendix A pH Profiles and Descriptions 5) Appendix N Summary Format

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List of Tables

Abbreviations

CalSil	Calcium Silicate (insulation)
CSS	Core Spray System
DIT	Design Information Transmittal
ECCS	Emergency Core Cooling System
GSI	Generic Safety Issue
HELB	High Energy Line Break
LOCA	Loss of Coolant Accident
NPSH	Net Positive Suction Head
NaOH	Sodium Hydroxide
PBNP	Point Beach Nuclear Plant
PWR	Pressurized Water Reactor
RCS	Reactor Coolant System
RMI	Reflective Metal Insulation
RPV	Reactor Pressure Vessel
RWST	Refueling Water Storage Tank
ZOI	Zone of Influence

1.0 PURPOSE

This evaluation discusses the inputs required to address the Nuclear Regulatory Commission (NRC) request for licensees to confirm their compliance with 10 CFR 50.46 (b)(5), as recently communicated in the NRC Generic Letter (GL 2004-02) titled "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," dated September 13, 2004, as well as NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Volumes 1 (Methodology) and 2 (Safety Evaluation), dated December 2004 [8].

The generic letter requires that licensees of Pressurized Water Reactors (PWR) perform mechanistic evaluations of their Emergency Core Cooling System (ECCS) and Containment Spray System (CSS) based on the potential susceptibility of PWR recirculation sump screens to debris blockage during design basis accidents requiring recirculation operation of ECCS or CSS, as well as on the potential for additional adverse downstream effects due to blockage of ECCS and CSS components and flow paths by debris which has bypassed the strainer. Debris blockage and subsequent flow restriction in the ECCS flow path could impede or prevent reactor coolant recirculation to the core, leading to inadequate core cooling and thus failing the requirements within 10CFR50.46. Regulatory Guide 1.82 has been revised to include evaluations of the concerns raised in the generic letter [2].

The results of these evaluations may be used to perform plant-specific strainer qualification testing. These activities involve head loss testing of a strainer module or modules to validate that the emergency systems will operate properly and within design margins following a Design Basis LOCA when the screen and sump recirculation water is fouled with resultant failed or precipitated materials.

NEI 04-07 states that licensees must evaluate the sump screen head loss consequences with an integrated approach which includes both fragmented debris (i.e. insulation) which has been generated, as well as corrosion products which may develop or precipitate following a LOCA [Reference 8 Vol. 2 Section 7.4]. Licensees must also ensure that the chemical effects test parameters applied during plant-specific strainer qualification testing (quantities and types of materials) are sufficiently bounding for their plant-specific conditions in order to ensure that the chemical effects issue has been addressed to the satisfaction of the regulator.

As a step toward addressing GL 2004-02, this evaluation specifically addresses the chemical evolutions which occur in the presence of postulated as-generated debris or other susceptible materials, including additional submerged or un-submerged (i.e. wetted) materials, as subject to acid or caustic fluids and in proximity of the containment sump following a Design Basis Loss-of-Coolant-Accident (LOCA). Note that debris generation, debris transport, downstream effects issues, and head loss calculations in the presence of a debris bed are normally addressed in separate evaluations.

The purpose of this document is to determine the type(s) and bounding quantities of chemical precipitates expected to form in the containment sump pool following a Design Basis LOCA. This evaluation has been performed based upon plant-specific design parameters primarily using the guidance published within WCAP-16530-NP and the associated Chemical Model Spreadsheet [1]. Sensitivity analyses were also performed to investigate the effects of applying specific reduction tactics directed within WCAP-16785-P [3].

This evaluation is required to understand the evolution of the chemical environment present inside the Unit 1 and 2 PBNP reactor containment and containment sump pools following a LOCA. The results of this evaluation may be used as inputs into the downstream effects evaluation or as chemical debris mixture inputs into sump strainer qualification testing for Point Beach, as results are used to direct the generation and subsequent introduction of chemical debris. The results of this evaluation will be compared to the concentration used as debris mixture inputs into previous Point Beach Sump Strainer Performance Testing. This is a safety related evaluation.

2.0 BACKGROUND

During a postulated LOCA inside containment, piping and equipment insulation can be fragmented by the jet forces exerted by the high pressure steam/water from a postulated break, and fall to the containment floor from the area of the break as 'generated' debris. This mixed debris, specific to the each plant, may consist of fibrous material (from the failure of insulation such as NUKON, and Temp Mat), particulates (from the failure of materials such as coatings, and microporous insulation), Reflective Mirror Insulation (RMI), and other miscellaneous debris types. This 'generated' debris will then mix with other latent and miscellaneous fibrous and particulate debris that has already become loose in containment as the sump pool fills with break water.

Immediately following a large break LOCA, it is also expected that the Containment Spray System (CSS) will actuate to mitigate a pressure spike in containment due to heat input from the high temperature break. The RWST (Refueling Water Storage Tank) source water will mix with concentrated sodium hydroxide (NaOH) to exit the system into containment through spray headers and nozzles as a borated alkaline spray solution. Once injected, the elevated pH spray solution will directly impinge upon and corrode any exposed containment inventory; including equipment, structural surfaces or coatings. Any ions that are dissociated by corrosion from inventory surfaces are then assumed to reach the sump pool, and subsequently be in proximity as possible reactants toward the precipitation of chemical debris.

When the Emergency Core Cooling System (ECCS) is actuated following a LOCA, the containment sump will supply water to support core cooling. In-containment barriers (sump strainers) are installed to prevent or hinder mixed debris from entering the ECCS. However, debris bed formation will occur on the sump screens, resulting in possible increases in head loss and damage to downstream components. Damage to downstream components could result from head loss increases at the containment sump strainer, as well as strainer debris bypass, as small debris potentially penetrates the sump screens and affects downstream components.

To address this ongoing concern regarding the GSI-191 related effect of chemical debris upon head losses at the sump strainers, this evaluation has been performed to assess the current PBNP Unit 1 and 2 designs and perform a full plant-specific evaluation of the chemical evolutions expected to occur due to material precipitation when generated debris or other susceptible materials are subject to acid or caustic fluid following a LOCA.

Recent work, directed by the Westinghouse Owner's Group (WOG), has sought to provide supplemental insight into the chemical processes that may occur in post-accident containment sump fluids by concentrating on more individual chemical reactions to ensure proper experimental control [1]. This work used the results of the Integrated Chemical Effect Test (ICET) Projects to target the chemical reactions expected to generate the most precipitate, through the application of more simplified configurations of individual insulation types, buffer solutions, and post-accident temperatures [10]. Specific materials and test parameters were selected based on plant-specific quantities reported and known reactivity characteristics of each material (see the following sections within Reference 1 for justification of elimination of the following materials: Zinc based materials - Section 6.2.2, Iron based materials - Section 6.2.3, Nickel and Copper based materials - Section 5.1.2, and organic materials (i.e. with respect to aluminum-based coatings)- Section 3.2).

This follow-up testing by Westinghouse was performed on individual representative containment materials, such as Aluminum, Concrete, Calcium Silicate (CalSil), Nukon Fiberglass, High Density Fiberglass, Mineral Wool, Min-K, Fiber Frax, Durablanket, Interam, Galvanized Steel, and Uncoated Carbon Steel. During the process, samples were taken of dissolved solutions and analyzed for the presence of Aluminum (Al), Calcium (Ca), Silicon (Si), Magnesium (Mg), Phosphorus (P), Sulfur (S), Iron (Fe), Zinc (Zn), and Titanium (Ti). It was shown that the total mass element release for aluminum, silicon, and calcium were the largest contributors to the dissolved solution, and that any precipitates would therefore most likely form of these elements [1].

Three specific chemical compounds were noted to precipitate during this testing dependent upon the debris mixture and test parameters [Reference 1 Section 6.1]. The results of the WOG test program indicated that the predominant chemical precipitates, dependent upon plant buffer type and the pH of the sump medium, were aluminum oxyhydroxide (AlOOH), sodium aluminum silicate ($NaAlSi_3O_8$), and calcium phosphate ($Ca_3(PO_4)_2$) (the latter only identified in the presence of trisodium phosphate (TSP)) [Reference 1 Section 6.1 & 6.4]. Other minor silicates could be precipitated. However, their concentration is expected to be minimal with respect to the dominant products (i.e. less than 5%) [1]. Therefore, the WCAP chemical model only considers the release rates of the principal elements or ions guiding relevant compound formation: aluminum, calcium and silicate.

Reference document WCAP-16530-NP, the "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," and its associated chemical effects model spreadsheet, were published as guidance to enable the industry to perform plant-specific chemical precipitate analyses which may be used toward facilitating chemical precipitate application to sump strainer testing activities [1].

Using the guidance and resources associated with WCAP-16530-NP, plant-specific containment material concentrations and densities, buffer solution type, as well as sump and spray pH and temperature transients post-accident, it is possible to predict the types and amounts of chemical precipitates which may form from the chemical reactivity of certain materials in the presence of specific aggressive chemical and thermal post-accident conditions.

3.0 ASSUMPTIONS

The following engineering assumptions are made in the course of the calculation to introduce additional conservatism and/or simplify the evaluation. Unverified assumptions that require confirmation of applicability of this calculation and its results are specifically noted. Unverified assumptions must be verified by Point Beach prior to use of the chemical effects calculation.

Sump Pool and Atmosphere/Spray Chemistry & Temperature Parameters with Time:

1. To address the extended time period required in 10 CFR50.46(b)(5), Reference 8 (Volume 2, Section 2.0, paragraph 2) states: "For this evaluation of PWR recirculation performance, the staff considers this extended time to be 30 days, and requires cooling by recirculation of coolant using the ECCS sump." Therefore, this evaluation assumes that the mission time for the ECCS operation is thirty (30) days, and that only the quantity precipitate which is generated up to that point must be calculated for use in head loss and downstream analyses.
2. Several base cases within this evaluation assume that there are no solubility limitations which would inhibit chemical precipitation (i.e. the sump is unmixed). This assumption applies conservatism in that all elemental materials generated in each liquid chemistry condition (sump / spray) will precipitate into a resulting chemical compound (described further in Section 4.0).
3. It is assumed from the information within Reference 5, as submitted by Point Beach, that a minimum recirculation initiation time of 27 minutes following the break, based on maximum attainable ECCS flow rates with a minimum RWST volume, is acceptable for use in the evaluation. Hence in each base case, a start time of 27 minutes is conservatively used. As stated in Reference 5, sensitivity studies could be performed to investigate the effect of a smaller LOCA, resulting in sump recirculation initiation at much longer times (i.e. 60 or 120 minutes, see Appendices E,F,K,L).
4. Based on the information reported within Reference 5, it is assumed that the containment spray system will be aligned to allow containment spray pumps to take suction from the containment sump following both the initiation of sump recirculation, and the point at which the RWST or NaOH injection is secured. At this point, for all cases, the spray pH would revert from the elevated initial injection pH (10) to the maximum sump pH (9.5), with the sump medium now considered as "mixed" (see Assumption 8 for more detail). Therefore, the time period following each initiation time of sump recirculation would indicate the lower 9.5 pH. In each case, the initial pH of containment spray would be assumed to be that of the maximum buffered spray solution (pH 10).

For clarity, the pH evolution scenarios investigated are summarized below (for graphical version see Appendices A.6 through A.8). Note that the supplemental sensitivity analyses are not intended to correspond to any realistic plant scenario. These runs are included for illustration purposes only to demonstrate the behavior of potential chemical effects as a function of the duration of spray injection vs. spray recirculation.

- Base Case Analyses (Cases 1.3 / 2.3) – Appendix A.6:
  - i. Start of Sump Recirculation at 27 Minutes
  - ii. Start of Spray Recirculation at 77 Minutes
  - iii. If sump recirculation initiates at 27 minutes, and single train operation results in RWST depletion after approximately 77 minutes, the spray pH would remain elevated (pH 10) until containment spray is rerouted to take suction from the sump (initiation of spray recirculation). Accounting for delays in mixing or suction switchover, the spray and sump pH will be assumed as "mixed" (maximum sump pH of 9.5) after approximately 100 minutes.
- Supplemental Sensitivity Analyses (Cases 1.4 / 2.4) – Appendix A.7:
  - i. Start of Sump Recirculation at 60 Minutes
  - ii. Start of Spray Recirculation at 100 Minutes
  - iii. If sump recirculation initiates at 60 minutes, the spray pH would once again remain elevated (pH 10) until containment spray is rerouted to take suction from the sump. Accounting for delays in mixing or suction switchover, the spray and sump pH will be assumed as "mixed" (maximum sump pH of 9.5) after approximately 123 minutes.
- Supplemental Sensitivity Analyses (Cases 1.5 / 2.5) – Appendix A.8:
  - i. Start of Sump Recirculation at 120 Minutes
  - ii. Start of Spray Recirculation at 123 Minutes
  - iii. In this case, if sump recirculation initiates at 120 minutes, the spray pH would once again remain elevated (pH 10) until containment spray is rerouted to take suction from the sump. Therefore, the spray and sump pH will be assumed as "mixed" (maximum sump pH of 9.5) after approximately 147 minutes.

5. Not Used

6. It is assumed from the information within Reference 5, as submitted by Point Beach, that containment spray should be evaluated to operate for a total spray duration of 6 hours (with the expectation that this may be viable for each unit in the future if usage of the Alternate Source Term is sought).

7. *It is assumed that the temperature* profile information submitted in Reference 5 is acceptable for use in this evaluation at this time. As these profiles are not yet internally supported / documented as Point Beach calculations, it must be assumed that these temperature values are ***unverified assumptions***.

8. It is assumed that the containment sump medium will become mixed following the initiation of sump recirculation for spreadsheet evolutions that will credit sump mixing. For both the *minimum* and *maximum* pH range conditions, this is assumed to occur once the spray pH reverts to the sump pH. Therefore, for the corresponding case sets outlined in Table 5-1, the spreadsheet (column G) has been altered to reflect this credit (Yes = 1). See Appendices A.6 through A.8 for pH evolution at this point.

Sump Pool Volume / Density:

9. As guided in Reference 1, if plants do not know the mass of the recirculation water for which the volume was calculated, the density of water at *the temperature at which the sump* pool volume was determined should be used. Reference 5 states that a temperature of approximately 60°F is appropriate for the volumes provided, and hence an average density of 62.4 lb/ft^3, as noted in Reference 5, is viable and conservative for use in all simulations (It is not necessary to use density corrections because this value is conservative for use in all simulations).

10. For conservatism, the maximum 'available' sump volume has been applied to most base case and supplemental test runs as the sump volume spreadsheet material input to ensure the appropriate and bounding calculation of the maximum *quantity of generated* precipitate/material. This value, 43,317 ft^3, was extracted from Reference 5.

11. All reported results indicate the calculation of simulation specific precipitate concentrations with respect to available sump or recirculation volume. This action is included for illustration purposes *only to exhibit the most* conservative (highest) concentration of generated precipitates from the final material quantities calculated. The minimum 'available' sump volume has been applied when calculating concentration. This value, 22,995 ft^3, was extracted from Reference 5.

General Volumes - Material / Insulation / Debris:

12. For primary base case simulations, the bounding / maximum amount of insulation generated for each insulation type for each unit was selected from the data for each break case in the Point Beach Units 1 and 2 Debris Generation Reports (see Appendix A.1) [5,12,13]. Though it is possible that these numbers may be bounded by a higher insulation volume, given the method of evaluation used in the Debris Generation Reports, as well as the existence of multiple additional conservatisms applied in the process of this chemical precipitation evaluation, it is believed that the data from the debris generation reports is representative of the volume of insulation which could fail and reach the sump water volume.
13. The volume of debris reported by Point Beach Debris Generation Calculations states quantities of generated insulation in terms of its original condition prior to LOCA initiation (i.e. as-fabricated) [12,13]. Therefore, the "as-fabricated" densities for each type of insulation from NEI 04-07 are used [5,8].
14. Generated material volumes include at a minimum any material which is generated during a LOCA. For certain materials (generic fiberglass, CalSil), generated material volumes are also assumed to include associated latent and miscellaneous debris.
15. Any insulation materials which do not fail during a LOCA are assumed to be unaffected by the spray. This unaffected volume includes any metal encapsulated / jacketed insulation materials (unless the jacketing is composed of an aluminum alloy).
16. All jacketed insulation materials are assumed to be composed of stainless steel, unless identified in the aluminum alloy inventory within Reference 5.

Fibrous Debris - Fiberglass Insulation:

17. Point Beach has a variety of mineral wool insulation installed at both Units 1 and 2 [5]. Based on Reference 22, this evaluation assumes that the variety of mineral wool installed has the material composition of 'MinWool', as listed in reference 1 Table 3.2-1 (steel slag + 5% phenolic resin binder, i.e. 40-52% calcium oxide, 10-19% silicon dioxide, 7-30% iron (II) oxide, 2-10% iron (III) oxide, 5% manganese oxide, and minor amounts of aluminum oxide, phosphorus pentoxide, sulfur and iron). This evaluation therefore also assumes that Point Beach mineral wool insulation has a similar degradation rate of 'MinWool'.
18. Given no alternatives from NEI 04-07 Table 4-1 for mineral wool insulation types, it is necessary to assume that the Point Beach mineral wool insulation installed at both Units 1 and 2 has an as-fabricated density of 10 lb/ft^3 [5,8]. This density is conservative within the

range of as-fabricated densities prescribed for generic mineral wool as reported within NEI 04-07 (4,6,8 and 10 lb/ft^3 are standard) [Reference 8 Vol. 1 Table 4-1].

General - Miscellaneous Debris:

19. In accordance with the current Point Beach design input transmittal, as well as the Unit 1 and 2 Debris Generation Evaluation, all miscellaneous debris reported as taking the form of 'foam' or 'film' are not applicable to the WCAP-16530-NP evaluation methodology, and therefore it is assumed that these materials are not expected to affect the quantity or type of precipitate generated in the sump following a LOCA [5,12,13]. Therefore, it will be assumed that only miscellaneous fibrous and particulate debris are acceptable as inputs into this evaluation.

Fibrous Debris - Latent & Miscellaneous:

20. For conservatism, when calculating the input volume of latent and miscellaneous fiber from material masses given in Reference 5, the as-fabricated density for Nukon will be used (density of Nukon = 2.4 lb/ft^3, the lowest NEI 04-07 reported fiberglass insulation density) [Reference 8 Vol. 1 Table 4-1]. This will help to ensure that the largest volume of latent and miscellaneous fiber is applied to the generic fiberglass material input when calculating the amount of subsequent corrosion / leaching.

21. The generic fiberglass insulation as-fabricated density will be applied in the actual chemical model for latent and miscellaneous fibrous debris using the values reported in NEI 04-07 [Reference 8 Vol. 1 Table 4-1].

22. Generic fiberglass has a higher leaching rate than other tested fiberglass insulation materials [Reference 1 Section 5.2.3]. Therefore, the volume of latent fibrous debris present in the sump will be applied to the generic fiberglass material input section.

Particulate Debris - Latent & Miscellaneous:

23. For conservatism, when calculating the input volume of latent and miscellaneous particulate from material masses given in Reference 5, the density for Asbestos will be used (density of Asbestos = 7 lb/ft^3, the lowest NEI 04-07 reported particulate insulation density) [Reference 8 Vol. 1 Table 4-1]. This will help to ensure that the largest volume of latent and miscellaneous particulate is applied to the CalSil material input when calculating the amount of subsequent corrosion / leaching.

24. The CalSil insulation as-fabricated density will be applied in the actual chemical model for latent and miscellaneous particulate debris using the values reported in NEI 04-07 [Reference 8 Vol. 1 Table 4-1].

25. This evaluation assumes that any latent or miscellaneous particulate debris has a degradation rate similar to that of CalSil. This assumption is valid as CalSil has exhibited the most significant material release rates when compared to other insulation material sub-types [Reference 1 Section 5.2.3]. Therefore, the volume of latent and miscellaneous particulate debris present in the sump will be applied to the CalSil material input section.

Particulate Debris - Coatings:

26. In accordance with guidance from industry research and documentation, it is unlikely that commonly found plant-specific coatings materials will break down to produce precipitate-forming species under the temperature and chemistry conditions tested [1,10].

27. It is assumed that the presence of aluminum-containing coatings materials will not result in the dissociation of additional aluminum ions into the sump medium. In most industry documentation, aluminum is primarily considered to be present due to the degradation of aluminum metal and fiber insulation [10,11,23]. Also, in accordance with guidance from industry research and documentation, it is unlikely that commonly found plant-specific coatings materials will break down to produce precipitate-forming species under the temperature and chemistry conditions tested (See Reference 1 Section 3.2) [1,10], and noted that the presence of some organics and inorganics can even serve to increase the solubility of aluminum [1,10,24].

Concrete in Containment:

28. It is assumed that the surface area delineated within Reference 5 includes all susceptible concrete within containment.

WCAP Spreadsheet Input & Errata Assumptions:

29. Certain spreadsheet errors were detected during internal and external review (see References 14 through 20 for more detail). Most of these reported errors are not applicable, or have been corrected within the spreadsheet revision used for this evaluation. The first error reported within Reference 16 has not been revised within the spreadsheet, but does not affect this evaluation given the plant-specific conditions and insulation debris types determined for Point Beach (no usage of Microtherm or Min-K insulation materials). The second error within Reference 16 has been corrected in the spreadsheet used for this evaluation. The error reported within Reference 20 has also not been revised within the spreadsheet, but does not affect this evaluation given the plant-specific conditions for Point Beach (errata is applicable to TSP only).

30. It is assumed that the apparent error on page 3 of LTR-SEE-I-01-14 (embedded within Reference 18) with respect to the first revised coefficient for aluminum release (51.15271 versus 51.1271), is insignificant in effect upon spreadsheet results. When the coefficient difference is iterated within the spreadsheet, no significant effect to overall total precipitate quantity by precipitate type is noted (less than 0.05% difference).

31. The spreadsheet does not determine release rates for the following materials/elements shown to be present in Table 5.1-2 of Reference 1.

    Aluminum release from CalSil
    Aluminum release from MIN-K
    Calcium release from MIN-K
    Aluminum release from Interam
    Calcium release from Interam

    With the exception of Aluminum release from Interam, the wt% of the element present in the insulation type is low or negligible (Interam and Min-K are not insulation types found at Point Beach Units 1 or 2). Therefore, it is viable to assume that the release of these particular elements from each associated insulation type is negligible or inapplicable given the other conservatisms applied during the process of this evaluation.

32. The values provided in the Design Information Transmittal (DIT) text will be used for all inputs, with the exception of temperature profile [5]. In this case, the excel profile attachment to Reference 5 will be used.

4.0 CHEMICAL MODEL SPREADSHEET

The chemical precipitates of primary concern identified during the WOG chemical effects testing activities are aluminum oxyhydroxide (AlOOH), sodium aluminum silicate ($NaAlSi_3O_8$), and calcium phosphate ($Ca_3(PO_4)_2$). Aluminum oxyhydroxide will normally precipitate for plants which contain aluminum either impacted by the spray or submerged in the containment sump pool. However, for plants with high silicon releases, sodium aluminum silicate may be formed instead. It is expected that available aluminum ions will react with silicon ions released from CalSil or fibrous insulation materials to form $NaAlSi_3O_8$. Calcium phosphate is not a concern for PBNP as the buffer solution utilized by Point Beach is sodium hydroxide (NaOH).

As PBNP employs sodium hydroxide (NaOH) as their containment spray buffer during accident conditions, it is not surprising that the predominant chemical precipitates would therefore likely be a mixture of aluminum oxyhydroxide (AlOOH) and sodium aluminum silicate ($NaAlSi_3O_8$) when the plant-specific debris mixture is subjected to a borated alkaline medium (such as that contributed by

NaOH in this case) [Reference 1 Section 6.1 & 6.4]. However, also noted in Section 6.4 of Reference 1 is the guidance that the preferential formation of these compounds is dependent upon concentration. Therefore, if the concentration of silicate is greater than 3.12 times the concentration of aluminum, all aluminum will likely precipitate as sodium aluminum silicate [1]. Given the presence of a significant amount of silicon-containing insulation types in this evaluation, it is viable that the generation of $NaAlSi_3O_8$ could preclude the degree of AlOOH compound generation.

The first stage of the chemical model predicts both the rate of dissolution and the solubility limits for select elements at certain points after LOCA has occurred. The quantity of the elements that make up the precipitates is calculated using the chemical model spreadsheet associated with WCAP-16530-NP. To determine the quantity of the key precipitates, it is assumed that sodium (Na), hydroxyl (OH), and phosphate (if applicable) will be present in excess [Reference 1 Section 6.4]. From these outputs, it is possible to determine precipitate quantities given the stoichiometry of expected chemical compounds.

During the second stage of the modeling process, all material that has dissolved into solution is conservatively assumed to form precipitates due to the limited solubility of the 'key' chemical precipitates [Reference 1 Section 6.4]. Solution concentrations of the dissolved elements and the potential mass of the three primary precipitate compounds are calculated with respect to time. In order to effectively eliminate any influence of variations in temperature upon the degree of precipitate formation, based on the low solubility of the three 'key' materials, the model assumes that all ions generated / leached following a LOCA will be available to form chemical precipitates. Therefore, 100 percent of dissociated aluminum ions (and calcium when in the presence of phosphate) will form chemical precipitates. However, as the solubility of calcium silicate increases at lower temperatures during constant pH conditions, it is expected that dissolved calcium will remain in solution in the absence of phosphate [1].

4.1 Chemical Model spreadsheet inputs

Initial Material Quantities

In order to calculate the quantity and concentration of chemical precipitation that will take place, the quantity of materials that would be exposed to reactor coolant and containment spray post-accident must be defined. The PBNP plant-specific inputs are reported in Appendix A.1 through A.4. They represent the maximum debris load without transport reductions. It is not advisable to use debris volumes that take credit for transport reductions, as all materials subject to the sump medium are generally assumed to degrade (i.e. dissociate) with time.

Material Densities

Material-specific density values are also required in order to convert insulation material inputs / volumes to mass. For all insulation materials, the "as-fabricated" density values given in Table 4-1 of NEI 04-07 or density values dictated by plant requirements may be used [5,8]. These inputs are reported in Appendix A.5.

pH and Temperature Transient Profiles

Separate time dependent pH and temperature profiles for both sump and spray conditions post-accident must also be developed. This information is applied through numeric integration of the tested material release rate equations to determine the cumulative release and dissolved concentration of each species with time [Reference 1 Table A-2]. These inputs are reported in Appendix A.6 through A.8.

5.0 SENSITIVITY ANALYSES

The effect on precipitate mass of altering several input parameters was explored using the chemical effects model. The parameters that were varied during this process include sump pool volume, time of sump recirculation initiation, mixing of sump pool medium, application of viable corrosion inhibition parameters, and debris generation insulation volumes by case [3,5]. The test parameter combinations explored for both Point Beach Units 1 and 2 during this sensitivity analysis are outlined in Table 5-1.

Table 5-1: Test Parameters – Units 1 & 2

Point Beach Nuclear Plant - Units 1 & 2 - Test Parameters										
	Variables									
	Unit	Debris Mix		Sump Volume		Recirc Start Time	Pool Volume Mixing		Corrosion Inhibition Parameters Applied	
Case		Bounding	Break Specific	Maximum	Minimum	(Minutes)	Unmixed	Mixed	Yes	No
Point Beach Nuclear Plant - Unit 1										
Case Set 1a: Bounding Debris Inputs										
1.1	1	X		X		27	X			X
1.2	1	X			X	27	X			X
1.3	1	X		X		27		X		X
1.4	1	X		X		60		X		X
1.5	1	X		X		120		X		X
1.6	1	X		X		27		X	X	
Case Set 1b: Debris Generation Case Inputs										
1.3.1	1		X	X		27		X		X
1.3.2	1		X	X		27		X		X
1.3.3	1		X	X		27		X		X
1.3.4	1		X	X		27		X		X
1.3.5	1		X	X		27		X		X
1.6.1	1		X	X		27		X	X	
1.6.2	1		X	X		27		X	X	
1.6.3	1		X	X		27		X	X	
1.6.4	1		X	X		27		X	X	
1.6.5	1		X	X		27		X	X	
Point Beach Nuclear Plant - Unit 2										
Case Set 2a: Bounding Debris Inputs										
2.1	2	X		X		27	X			X
2.2	2	X			X	27	X			X
2.3	2	X		X		27		X		X
2.4	2	X		X		60		X		X
2.5	2	X		X		120		X		X
2.6	2	X		X		27		X	X	
Case Set 2b: Debris Generation Case Inputs										
2.3.1	2		X	X		27		X		X
2.3.2	2		X	X		27		X		X
2.3.3	2		X	X		27		X		X
2.3.4	2		X	X		27		X		X
2.3.5	2		X	X		27		X		X
2.3.6	2		X	X		27		X		X
2.3.7	2		X	X		27		X		X
2.6.1	2		X	X		27		X	X	
2.6.2	2		X	X		27		X	X	
2.6.3	2		X	X		27		X	X	
2.6.4	2		X	X		27		X	X	
2.6.5	2		X	X		27		X	X	
2.6.6	2		X	X		27		X	X	
2.6.7	2		X	X		27		X	X	

5.1 Case Set 1a/2a: Bounding Debris Inputs

Base Case Analyses:
Cases 1.1 – 1.3 and 2.1 – 2.3

For each unit, the first three runs within each case set are the base case simulations. These tests were performed while varying a combination of sump water volume and mixed sump inputs. The magnitude of the sump volume was varied between the maximum and minimum recirculation water volumes reported by Point Beach and was found to significantly affect the degree of precipitation. Base case numbers 1 and 3 were performed at the maximum sump volume (43,317 ft^3), and base case number 2 was performed at the minimum sump volume (22,995 ft^3) [5]. For each of the base cases, the appropriate transient pH and temperature profile may be found in Appendix A.6, reflecting the usage of a maximum pH profile and sump recirculation initiation at 27 minutes. Chemical model material and sump volume inputs are reported in Appendix A, and model predictions for elemental release and precipitation are reported for Unit 1 in Appendices B through D, and for Unit 2 in Appendices H through J. Bounding debris generation volumes were used as material inputs for all base cases (see process in Appendix A.2).

Supplemental Analyses:
Cases 1.4 – 1.5 and 2.4 – 2.5

For each unit, the following two sensitivity runs are supplemental analyses performed to investigate the effect of increasing the time to sump recirculation initiation on the degree of precipitation. Supplemental case numbers 4 and 5 were performed for each unit at the maximum sump volume (43,317 ft^3) [5][1]. For these cases, the appropriate transient pH and temperature profile may be found in Appendix A.7 and A.8, reflecting the usage of a maximum pH profile and recirculation initiation at 60 and 120 minutes respectively [5]. Chemical model material and sump volume inputs are reported in Appendix A (identical to the base cases), and model predictions for elemental release and precipitation are reported for Unit 1 in Appendices E and F, and for Unit 2 in Appendices K and L.

Supplemental Analyses: Additional Input Evaluations
Cases 1.6 and 2.6:

For each unit, the next sensitivity run is a supplemental analysis performed to investigate the effect of taking credit for WCAP-16785-P inhibition and solubility effects on the degree of precipitation. For this supplemental case, the appropriate transient pH and temperature profile may be found in Appendix A.6, reflecting the usage of a maximum pH profile and sump recirculation initiation at 27 minutes [5]. Other specific manipulations were performed within the chemical model spreadsheet, as outlined in WCAP-16785-P. Chemical model material and sump volume inputs are reported in Appendix A (as

[1] All supplemental analyses (Cases 4 through 6) are performed using base case 3 parameters for each unit.

identical to each base case), and model predictions for elemental release and precipitation are reported for Unit 1 in Appendix G, and for Unit 2 in Appendix M.

5.2 Case Set 1b/2b: Debris Generation Case Inputs

Supplemental Analyses: Additional Input Evaluations – All Debris Gen Cases
Cases 1.3.1 – 1.3.5 and 2.3.1 - 2.3.7:

For each unit, the sub-cases have been performed using 1.3 and 2.3 base cases to ensure that all debris combinations are investigated in the process of this evaluation, as identified through debris generation calculations. All sub-case 1.3 and 2.3 simulations were performed at the maximum sump volume (43,317 ft^3), and the transient pH and temperature profile be found in Appendix A.6, reflecting the usage of a maximum pH profile and sump recirculation initiation at 27 minutes. Chemical model material and sump volume inputs are reported for Unit 1 in Appendix A.3, and for Unit 2 in Appendix A.4. A summary of model predictions for elemental release and precipitation are reported for Unit 1 in Appendix N.1, and for Unit 2 and Appendix N.2.

Supplemental Analyses: Additional Input Evaluations – All Debris Gen Cases
Cases 1.6.1 – 1.6.5 and 2.6.1 - 2.6.7:

For each unit, the last set of sensitivity runs are supplemental analyses performed to investigate the effect of taking credit for WCAP-16785-P inhibition and solubility effects on the degree of precipitation for each individual debris generation case. For these supplemental cases, the appropriate transient pH and temperature profile may be found in Appendix A.6, reflecting the usage of a maximum pH profile and sump recirculation initiation at 27 minutes [5]. Other specific manipulations were performed within the chemical model spreadsheet, as outlined in WCAP-16785-P, and as directed within Reference 18. Chemical model material and sump volume inputs are reported for Unit 1 in Appendix A.3, and for Unit 2 in Appendix A.4. A summary of model predictions for elemental release and precipitation are reported for Unit 1 in Appendix N.1, and for Unit 2 and Appendix N.2.

6.0 RESULT SUMMARY

A summary of resultant precipitate outputs is outlined in Table 6-1 for the combination of test parameters explored in the process of this evaluation (see Table 5-1 for Test Parameters).[2] Of each unit set of base cases, case number 1 resulted in the most significant amount of material precipitation. As identified within Section 5.0, these test runs were performed at the maximum sump pH profile and other test parameters reported in Table 5.1 for each of the Point Beach Nuclear Plants.

[2] Table 6-1 states the Mass of Silicon and Aluminum Release in a 30 day simulation period.

Table 6-1: Test Outputs for Units 1 & 2[3]

Point Beach Nuclear Plant - Unit 1				Point Beach Nuclear Plant - Unit 2			
Case 1.1	Base Case Analysis			Case 2.1	Base Case Analysis		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Mass of Silicon Release =	578.04	kg		Mass of Silicon Release =	616.25	kg
	Silicon Concentration*=	887.610	mg/L		Silicon Concentration*=	946.283	mg/L
	Mass of Aluminum Release =	25.54	kg		Mass of Aluminum Release =	28.27	kg
	Aluminum Concentration*=	39.218	mg/L		Aluminum Concentration*=	43.410	mg/L
	$NaAlSi_3O_8$ Precipitate Mass =	248.252	kg		$NaAlSi_3O_8$ Precipitate Mass =	274.808	kg
	AlOOH Precipitate Mass =	0	kg		AlOOH Precipitate Mass =	0	kg
	$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg		$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg
	Total Precipitate Mass =	248.252	kg		Total Precipitate Mass =	274.808	kg
	Minimum Sump Volume =	22995	ft^3		Minimum Sump Volume =	22995	ft^3
Case 1.2	Base Case Analysis			Case 2.2	Base Case Analysis		
	Minimum Sump Volume =	22995	ft^3		Minimum Sump Volume =	22995	ft^3
	Mass of Silicon Release =	349.8	kg		Mass of Silicon Release =	405.49	kg
	Silicon Concentration*=	537.136	mg/L		Silicon Concentration*=	622.651	mg/L
	Mass of Aluminum Release =	17.46	kg		Mass of Aluminum Release =	18.77	kg
	Aluminum Concentration*=	26.811	mg/L		Aluminum Concentration*=	28.822	mg/L
	$NaAlSi_3O_8$ Precipitate Mass =	169.676	kg		$NaAlSi_3O_8$ Precipitate Mass =	182.418	kg
	AlOOH Precipitate Mass =	0	kg		AlOOH Precipitate Mass =	0	kg
	$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg		$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg
	Total Precipitate Mass =	169.676	kg		Total Precipitate Mass =	182.418	kg
	Minimum Sump Volume =	22995	ft^3		Minimum Sump Volume =	22995	ft^3
Case 1.3	Base Case Analysis			Case 2.3	Base Case Analysis		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Mass of Silicon Release =	447.06	kg		Mass of Silicon Release =	430.21	kg
	Silicon Concentration*=	686.484	mg/L		Silicon Concentration*=	660.609	mg/L
	Mass of Aluminum Release =	14.86	kg		Mass of Aluminum Release =	17.94	kg
	Aluminum Concentration*=	22.818	mg/L		Aluminum Concentration*=	27.548	mg/L
	$NaAlSi_3O_8$ Precipitate Mass =	144.434	kg		$NaAlSi_3O_8$ Precipitate Mass =	174.405	kg
	AlOOH Precipitate Mass =	0	kg		AlOOH Precipitate Mass =	0	kg
	$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg		$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg
	Total Precipitate Mass =	144.434	kg		Total Precipitate Mass =	174.405	kg
	Minimum Sump Volume =	22995	ft^3		Minimum Sump Volume =	22995	ft^3
Case 1.4	Supplemental Analysis			Case 2.4	Supplemental Analysis		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Mass of Silicon Release =	447.07	kg		Mass of Silicon Release =	430.23	kg
	Silicon Concentration*=	686.499	mg/L		Silicon Concentration*=	660.640	mg/L
	Mass of Aluminum Release =	14.86	kg		Mass of Aluminum Release =	19.08	kg
	Aluminum Concentration*=	22.818	mg/L		Aluminum Concentration*=	29.298	mg/L
	$NaAlSi_3O_8$ Precipitate Mass =	144.392	kg		$NaAlSi_3O_8$ Precipitate Mass =	185.435	kg
	AlOOH Precipitate Mass =	0	kg		AlOOH Precipitate Mass =	0	kg
	$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg		$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg
	Total Precipitate Mass =	144.392	kg		Total Precipitate Mass =	185.435	kg
	Minimum Sump Volume =	22995	ft^3		Minimum Sump Volume =	22995	ft^3
Case 1.5	Supplemental Analysis			Case 2.5	Supplemental Analysis		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Mass of Silicon Release =	447.07	kg		Mass of Silicon Release =	430.32	kg
	Silicon Concentration*=	686.499	mg/L		Silicon Concentration*=	660.778	mg/L
	Mass of Aluminum Release =	14.85	kg		Mass of Aluminum Release =	19.97	kg
	Aluminum Concentration*=	22.803	mg/L		Aluminum Concentration*=	30.665	mg/L
	$NaAlSi_3O_8$ Precipitate Mass =	144.301	kg		$NaAlSi_3O_8$ Precipitate Mass =	194.119	kg
	AlOOH Precipitate Mass =	0	kg		AlOOH Precipitate Mass =	0	kg
	$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg		$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg
	Total Precipitate Mass =	144.301	kg		Total Precipitate Mass =	194.119	kg
	Minimum Sump Volume =	22995	ft^3		Minimum Sump Volume =	22995	ft^3
Case 1.6	Supplemental Analysis - Additional Input Evaluations			Case 2.6	Supplemental Analysis - Additional Input Evaluations		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Mass of Silicon Release =	447.06	kg		Mass of Silicon Release =	430.21	kg
	Silicon Concentration*=	686.484	mg/L		Silicon Concentration*=	660.609	mg/L
	Mass of Aluminum Release =	14.05	kg		Mass of Aluminum Release =	16.12	kg
	Aluminum Concentration*=	21.574	mg/L		Aluminum Concentration*=	24.753	mg/L
	$NaAlSi_3O_8$ Precipitate Mass =	136.561	kg		$NaAlSi_3O_8$ Precipitate Mass =	156.712	kg
	AlOOH Precipitate Mass =	0	kg		AlOOH Precipitate Mass =	0	kg
	$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg		$Ca_3(PO_4)_2$ Precipitate Mass =	0	kg
	Total Precipitate Mass =	136.561	kg		Total Precipitate Mass =	156.712	kg
	Minimum Sump Volume =	22995	ft^3		Minimum Sump Volume =	22995	ft^3

[3] The "Concentration" values reported in Table 6-1 are for illustration purposes only as these values are normally dependent on strainer test volume. In the above cases, "Concentration" is determined using the minimum sump volume as provided for this evaluation (22,995 ft^3), which is not the value reported and utilized in previous chemical effects evaluation revisions (832700 L) [4]. These values are provided only to allow cross reference to previous calculations and supporting documentation.

One common thread throughout all cases is the fact that no chemical precipitation of AlOOH or $Ca_3(PO_4)_2$ was observed to occur due to the degradation of debris in containment. Only sodium aluminum silicate ($NaAlSi_3O_8$) was determined to precipitate in all cases. Therefore, as predicted in Section 4.0, given the presence of an adequate amount of silicon-containing insulation types for each unit (CalSil or fibrous-based), the generation of $NaAlSi_3O_8$ has been found to preclude the degree of AlOOH compound generation. In the case of precipitate formation for either compound, it should be noted from each chemical formula that aluminum ions are the limiting component for chemical debris precipitation in all cases.

It can also be concluded that the higher level of chemical precipitation for Unit 2 is simply due to higher quantities of material inputs (primarily Nukon: aluminum and silicon containing insulation debris), as all other input parameters were identical between the two case sets (temperature and pH transient profiles, sump mixing, material density inputs).

It is important to also point out that the presence of a higher pH sump / spray atmosphere in this particulate debris and buffer configuration will also significantly affect precipitation, and any future decreases in pH will benefit each unit in terms of expected resultant head losses at the strainer (see Section 3.0 Assumptions).

6.1 Case Set 1a/2a: Bounding Debris Inputs

Base Case Analyses:
Cases 1.1 – 1.3 and 2.1 – 2.3

It can be concluded from these cases that higher levels of chemical precipitation noted between Cases 1.1/2.1 and 1.2/2.2 are simply due to the conservative application of a significantly higher water volume (minimum vs. maximum), resulting in increased chemical precipitation due to the volume available for solution of dissociated ions. The assumption of the minimum sump volume in Case 1.2/2.2 had a marked effect on final precipitate quantity when compared to Case 1.1/2.1, resulting in greater than 30% reduction in precipitate overall quantity.

As evidenced in the above simulated test results, increased chemical precipitation can result from the presence of a higher sump volume. Dependence upon sump volume is normally attributable to the fact that the release rate of aluminum from these materials decreases with time as the solubility limit is approached, and that the release rate from aluminum silicate insulation materials decreases with increasing concentration of dissolved aluminum from all sources due to the common ion effect [Reference 1 Section 6.1]. These conclusions are made for these cases as all other input parameters between the first two cases were identical (temperature and pH transient profiles, unmixed sump medium, material density inputs).

The introduction of sump "mixing" in these simulations (Case 1.3/2.3), also had a significant effect on final precipitate quantity when compared to Case 1.1/2.1. Applying sump mixing only after recirculation is expected to occur (see Assumption 8) resulted in greater than 40% reduction in precipitate overall quantity. Through this case, it is made obvious that this option within the spreadsheet has a substantial effect on precipitate generation as it allows the elemental mass already released into the sump solution to impact the dissolution rate from each material containing that element [1].

Chemical model predictions for elemental release and precipitation are reported for Unit 1 in Appendices B through D, and for Unit 2 in Appendices H through J.

Supplemental Analyses:
Cases 1.4 – 1.5 and 2.4 – 2.5

The manipulation of sump recirculation initiation time start had little to no effect on the final precipitate quantity determined to generate using the spreadsheet. This is likely a primary result of a greater percentage of exposed aluminum source materials as opposed to any submerged areas for both units. Only the exposed source materials would be affected with any significant recirculation changes. Though the pH passing through the containment spray injection header is elevated for a longer period when recirculation initiation is delayed, the time frame of pH subjection does not appear to be long enough for exposed aluminum materials to result in any significant increases in dissociation / degradation.

Chemical model predictions for elemental release and precipitation are reported for Unit 1 in Appendices E and F, and for Unit 2 in Appendices K and L.

Supplemental Analyses: Additional Input Evaluations (WCAP-16785-P)
Cases 1.6 and 2.6:

The application of solubility and inhibition limiters, as guided in References 3 and 18, had some effect on chemical precipitation. The following WCAP-16785-P simulations were applied to each unit base case (1.3,2.3):

- Silicate Inhibition: for plants exceeding 75 ppm Silicon,
- Silicate Inhibition: for plants with 50 to 75 ppm Silicon,
- Aluminum Oxyhydroxide Solubility Limit.

All other inhibition/solubility cases were not applicable for Point Beach, and were therefore not applied during these evaluations.

These supplemental cases are labeled as 1.6 and 2.6 in the results above, and model predictions for elemental release and precipitation are reported for Unit 1 in Appendix G, and for Unit 2 in Appendix M.

Only the Silicate Inhibition for a plant exceeding 75 ppm had any affect on the final total precipitate quantity. When comparing Cases 1.3 (mixed base case) and 1.6 (mixed additional inputs), with all other conditions identical, the change results in approximately 5% reduction in precipitate overall quantity. When comparing Cases 2.3 (mixed base case) and 2.6 (mixed additional inputs), with all other conditions identical, the change results in approximately 10% reduction in precipitate overall quantity. Though these sensitivity runs did result in some reduction of precipitate quantity, it may be advisable for the user to consider application of only the base case simulations until regulator approval is granted or expected for Reference 3.

6.2 **Case Set 1b/2b:** Debris Generation Case Inputs

Supplemental Analyses: Additional Input Evaluations – All Debris Gen Cases
Cases 1.3.1 – 1.3.5 and 2.3.1 - 2.3.7:

These cases are purely debris generation case specific. Each separate simulation corresponds to pure debris generation case debris output results, and has been included to allow for parametric review by the user. Cases 1.3/2.3 have been used as the correlating base cases for each unit. Any variability in precipitate results is directly related to the fibrous and insulation debris quantities applied (aluminum source materials, temperature and pH profiles, and sump mixing were all constant).

Chemical model material and sump volume inputs are reported for Unit 1 in Appendix A.3, and for Unit 2 in Appendix A.4. A summary of model predictions for elemental release and precipitation are reported for Unit 1 in Appendix N.1, and for Unit 2 and Appendix N.2.

Supplemental Analyses: Additional Input Evaluations – All Debris Gen Cases
Cases 1.6.1 – 1.6.5 and 2.6.1 - 2.6.7:

The application of solubility and inhibition limiters to specific debris generation simulations also had some effect on chemical precipitation. As for cases 1.6/2.6 above, the following WCAP-16785-P simulations were applied to each debris generation "base case" (1.3.1-1.3.5, 2.3.1–2.3.7):

- Silicate Inhibition: for plants exceeding 75 ppm Silicon,
- Silicate Inhibition: for plants with 50 to 75 ppm Silicon,
- *Aluminum Oxyhydroxide Solubility Limit.*

All other inhibition/solubility cases were not applicable for Point Beach, and were therefore not applied during these evaluations. These supplemental cases are labeled as 1.6.X and 2.6.X in the results above, and model predictions for elemental release and precipitation are reported for Unit 1 in Appendix N.1, and for Unit 2 in Appendix N.2.

Once again, only the Silicate Inhibition for a plant exceeding 75 ppm had any affect on the final total precipitate quantity. Though these sensitivity runs did result in some reduction of precipitate quantity, it may be advisable for the user to consider application of only the base case simulations until regulator approval is granted or expected for Reference 3.

Comparison to Past Testing Activities

If a direct comparison to past testing is desired (see also Reference 4) to be consistent with the previously performed chemical precipitation evaluation, this evaluation will use the 832700 L (Reference 4 Section 5.0 Min Sump Volume) value for sump volume for illustration purposes only.[4]

A summary of resultant precipitate concentrations is outlined in Table 6-2 for the combination of test parameters explored in the process of this evaluation (see Table 5-1 for Test Parameters, and Table 6-1 for original test results for the applicable cases). Note the significant difference in the volume at which the maximum precipitate mass was calculated (from Appendix A, Max Sump Volume = 43317 ft^3 = 1226763L). Note: Future strainer testing activities will likely use a scaled correlation to strainer size to determine quantity to be introduced to strainer testing activities, therefore direct comparison to previous strainer testing or calculation results is not recommended other than for illustration purposes only.

Table 6-2: Comparison Concentrations for Units 1 & 2

Point Beach Nuclear Plant - Unit 1				Point Beach Nuclear Plant - Unit 2			
Case 1.1	**Base Case Analysis - unmixed**			**Case 2.1**	**Base Case Analysis - unmixed**		
	Minimum Sump Volume =	832700	L		Minimum Sump Volume =	832700	L
	Total Precipitate Mass =	248.252	kg		Total Precipitate Mass =	274.808	kg
	Resultant Concentration*=	**298.129**	mg/L		Resultant Concentration*=	**330.020**	mg/L
Case 1.3	**Base Case Analysis - mixed**			**Case 2.3**	**Base Case Analysis - mixed**		
	Minimum Sump Volume =	832700	L		Minimum Sump Volume =	832700	L
	Total Precipitate Mass =	144.434	kg		Total Precipitate Mass =	174.405	kg
	Resultant Concentration*=	**173.452**	mg/L		Resultant Concentration*=	**209.445**	mg/L

The concentration of chemical effect precipitate material that was used as a physical input into the debris configuration developed for the PBNP Sump Strainer Performance Testing to enable the simulation of the most representative chemical environment present inside the PBNP reactor containment water pool after a loss-of-coolant accident was 589 mg/L, much greater than even the most conservative simulations reported in this evaluation [4].

[4] The "Concentration" values reported in Table 6-1 are included for illustration purposes only.

7.0 CONCLUSION

The results of these model predictions have been briefly summarized for review in Table 7-1 below[5].

Table 7-1: Test Summary – Units 1 & 2

Point Beach Nuclear Plant Unit 1				Point Beach Nuclear Plant Unit 2			
Case 1.1	**Base Case Analysis**			**Case 2.1**	**Base Case Analysis**		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Total Precipitate Mass =	**248.252**	kg		Total Precipitate Mass =	**274.808**	kg
Case 1.2	**Base Case Analysis**			**Case 2.2**	**Base Case Analysis**		
	Minimum Sump Volume =	22995	ft^3		Minimum Sump Volume =	22995	ft^3
	Total Precipitate Mass =	**169.676**	kg		Total Precipitate Mass =	**182.418**	kg
Case 1.3	**Base Case Analysis**			**Case 2.3**	**Base Case Analysis**		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Total Precipitate Mass =	**144.434**	kg		Total Precipitate Mass =	**174.405**	kg
Case 1.4	**Supplemental Analysis**			**Case 2.4**	**Supplemental Analysis**		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Total Precipitate Mass =	**144.392**	kg		Total Precipitate Mass =	**185.435**	kg
Case 1.5	**Supplemental Analysis**			**Case 2.5**	**Supplemental Analysis**		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Total Precipitate Mass =	**144.301**	kg		Total Precipitate Mass =	**194.119**	kg
Case 1.6	**Supplemental Analysis**			**Case 2.6**	**Supplemental Analysis**		
	Maximum Sump Volume =	43317	ft^3		Maximum Sump Volume =	43317	ft^3
	Total Precipitate Mass =	**136.561**	kg		Total Precipitate Mass =	**156.712**	kg

For each unit, of the three base cases, run number 1 resulted in the most significant amount of material precipitation (unmixed assumption). Therefore, the maximum conservative mass of chemical precipitate materials for Unit 1 is equal to 248.252 kg ($NaAlSi_3O_8$), and the maximum conservative mass of chemical precipitate materials for Unit 2 is equal to 274.808 kg ($NaAlSi_3O_8$). However, if 'mixed' evaluation outputs are desired for final use in chemical debris calculations, the maximum mass of chemical precipitate materials for Unit 1 is equal to 144.434 kg ($NaAlSi_3O_8$), and the maximum conservative mass of chemical precipitate materials for Unit 2 is equal to 174.405 kg ($NaAlSi_3O_8$) for plant-specific conditions that include the initiation of sump recirculation 27 minutes after the accident has occurred[6].

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[5] As identified within Section 5.0, these test runs were performed at the maximum sump pH profile, and other test parameters reported in Table 5.1 for each of the Point Beach Nuclear Plants.

[6] Additional sensitivity runs have been incorporated into this report to permit chemical debris margin allowance changes should plant-specific parameters evolve after this report is finalized (i.e. time of sump recirculation initiation).

With respect to concentration, it can also be validated that the concentration of chemical effect precipitate material used as a physical input into PBNP Sump Strainer Performance Testing (589 mg/L) is conservative [4]. Therefore, this evaluation has substantiated the type and concentration of chemical effects material which has been conservatively evaluated in previous Chemical Effect Precipitation analyses as likely to precipitate in the event of a loss-of-coolant accident at the PBNP Power Station.

8.0 REFERENCES

[1] * WCAP-16530-NP & Spreadsheet, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191", February 2006.

[2] Regulatory Guide 1.82 Revision 3, "Water Sources for Long-Term Recirculation Cooling Following a Loss-Of-Coolant-Accident," November 2003.

[3] * WCAP-16785-P, "Evaluation of Additional Inputs to the WCAP-16530-NP Chemical Model", April 2007.

[4] AREVA NP Doc. No 51-9010780-001, "Chemical Effects Material Selection for Point Beach Sump Strainer Performance Test," April 2006.

[5] AREVA NP Doc. No 38-9056238-000, "Design Information Transmittal (DIT) in support of GSI-191 Chemical Effects Evaluation - Point Beach," July 2007 (NPL 2007-0135).

[6] AREVA NP Doc. No 38-9018142-000, "Design Information Transmittal (DIT) from Tom Kendall of Point Beach to Support," April 2006 (NPL 2006-0052).

[7] AREVA NP Doc. No 38-9003352-000, "Point Beach GSI-191 Downstream Effects Input," October 2005 (NPL 2005-0193).

[8] NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Volumes 1 (Methodology) and 2 (Safety Evaluation), December 2004.

[9] NUREG/CR-6913, "Chemical Effects Head-Loss Research in Support of Generic Safety Issue 191", U.S. NRC, December 2006.

[10] NUREG/CR-6914, "Integrated Chemical Effects Test Project: Consolidated Data Report," Los Alamos National Laboratory, December 2006.

[11] NUREG/CR-6873, "Corrosion Rate Measurements and Chemical Speciation of Corrosion Products Using Thermodynamic Modeling of Debris Components to Support GSI-191", U.S. NRC, April 2005.

[12] AREVA NP Doc. No 32-5050092-002, "DEBRIS GENERATION EVALUATION FOR POINT BEACH NUCLEAR PLANT UNIT 1," June 2006.

[13] AREVA NP Doc. No 32-5052938-003, "DEBRIS GENERATION EVALUATION FOR POINT BEACH NUCLEAR PLANT UNIT 2," June 2006.

[14] * WOG-06-102, Errata to WCAP-16530-NP, "Distribution of Errata to WCAP-16530-NP, "Method for Evaluating Post-Accident Chemical Effects in Containment Sump Fluids" (PA-SEE-0275)," March 2006.

[15] * WOG-06-107, Errata to WCAP-16530-NP, "PWR Owners Group Letter to NRC Regarding Error Corrections to WCAP-16530-NP (PA-SEE-0275)," March 2006.

[16] * WOG-06-232, Errata to WCAP-16530-NP, "PWR Owners Group Letter Regarding Additional Error Corrections to WCAP-16530-NP (PA-SEE-0275)," July 2006.

[17] * OG-07-270 "New Settling Rate Criteria for Precipitates Generated in Accordance with WCAP-16530-NP (PA-SEE-0275)", June 2007.

[18] * OG-07-282 "Instructions to Evaluate Specific Inputs for WCAP-16785-NP; PA-SEE-0354, "Incorporation of Additional Inputs in the Chemical Effects Spreadsheet"," June 2007.

[19] * OG-06-255, Errata to WCAP-16530-NP, "PWR Owners Group Letter Releasing Revised Chemical Model Spreadsheet From WCAP-16530-NP (PA-SEE-0275)," August 2006.

[20] * OG-06-273, Errata to WCAP-16530-NP, "PWR Owners Group Method Description of Error Discovered August 15, 2006 in Revised Chemical Model Spreadsheet (PA-SEE-0275)," August 2006.

[21] Lindeburg, Michael R., Mechanical Engineering Reference Manual for the PE Exam, Eleventh Edition, Professional Publications, Inc., 2001.

[22] AREVA NP Doc. No 38-9057297-000, "Design Information Transmittal (DIT) from Tom Kendall of Point Beach to Support," August 2006 (NPL 2007-0145).

[23] NUREG/CR-6912, "GSI-191 PWR Sump Screen Blockage Chemical Effects Tests; Thermodynamic Simulations", U.S. NRC, December 2006.

[24] NUREG/CR-6915, "Aluminum Chemistry in a Prototypical Post-Loss-of-Coolant-Accident, Pressurized-Water-Reactor Containment Environment", U.S. NRC, December 2006.

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Note:

* This reference is not retrievable from AREVA NP document control system, but can be retrieved through the Westinghouse Owner's Group. Per AREVA NP administrative procedure, 0402-01 Appendix 2, these references are acceptable.

PM/PE Signature: ______ Date: 9/27/07

F. Gartland

APPENDIX A: GENERIC TEST INPUTS

A.1 Primary Evaluation Inputs Post-Accident – Base Cases

Point Beach List of Inputs - *Material Quantity & Input Affected*

Class	Material / Input	Point Beach Inputs	Source of Data Ref. 5	Notes
Coolant	Sump Pool Volume (ft^3)	Min.= 22995 ft^3 Max.= 43317 ft^3		
	Buffer Type	Sodium Hydroxide (NaOH)		
	Min & Max Sump Pool pH	Min.= 7.0 Max.= 9.5		
	Min & Max Spray pH	Min.= 8.0 Max.= 10.0		
	Initiation of Spray Injection	0 seconds		
	Initiation of Sump Recirculation	Base: 27 minutes Other: 60 minutes Other: 120 minutes		See Assumptions for information regarding additional sensitivity run parameters.
	Total Period of Spray Injection	6 hours		See Assumptions for more information.
	Spray & Sump Temperature Profiles	see notes		Provided in Appendix A
Metallic Aluminum	Aluminum Submerged (ft^2)	29.2		
	Aluminum Submerged (lbm)	59		
	Aluminum Not-Submerged (ft^2)	306.25		
	Aluminum Not-Submerged (lbm)	325		
Calcium Silicate	CalSil Insulation (ft^3) - Unit 1	132.8		Unit 1: CalSil Insulation Debris Generated (113.05) + Total Additional Particulate Debris (19.7)
	CalSil Insulation (ft^3) - Unit 2	143.9		Unit 2: CalSil Insulation Debris Generated (122.72) + Total Additional Particulate Debris (21.19)
	Asbestos Insulation (ft^3) - Unit 1	296.74		
	Asbestos Insulation (ft^3) - Unit 2	116.07		
	Kaylo Insulation (ft^3)	0		
	Unibestos Insulation (ft^3)	0		
E-glass	Fiberglass Insulation (ft^3) - Unit 1	229.0		Unit 1: Fiberglass Debris Generated (181.4) + Total Additional Fibrous Debris (47.6)
	Fiberglass Insulation (ft^3) - Unit 2	129.5		Unit 2: Fiberglass Debris Generated (114.7) + Total Additional Fibrous Debris (14.8)
	NUKON (ft^3) - Unit 1	0		
	NUKON (ft^3) - Unit 2	1046.65		
	Temp-Mat (ft^3) - Unit 1	23.44		
	Temp-Mat (ft^3) - Unit 2	99.57		
	Thermal Wrap (ft^3)	0		
Silica Powder	Microtherm (ft^3)	0		
	Min-K (ft^3)	0		
Mineral Wool	Min-Wool (ft^3) - Unit 1	218.99		See Reference 22 for more information.
	Min-Wool (ft^3) - Unit 2	323.2		See Reference 22 for more information.
	Rock Wool (ft^3)	0		
Aluminum Silicate	Cerablanket (ft^3)	0		
	FiberFrax Durablanket (ft^3)	0		
	Kaowool (ft^3)	0		
	Mat-Ceramic (ft^3)	0		
	Mineral Fiber (ft^3)	0		
	PAROC Mineral Wool (ft^3)	0		
Concrete	Concrete (ft^2)	10000		
Trisodium Phosphate	Trisodium Phosphate Hydrate (lbm)	0		
Interam	Interam (ft^3)	0		

Point Beach List of Inputs - ***Material Quantity & Input Affected***

Class	Material / Input	Point Beach Inputs	Source of Data Ref. 5	Notes
The following are latent and miscellaneous debris volumes used to supplement the above spreadsheet material inputs:				
Miscellaneous Debris	Miscellaneous Fiber (ft^3) - Unit 1	38.2		Foam and Film excluded per References 5, 12 and 13.
	Miscellaneous Fiber (ft^3) - Unit 2	5.43		Foam and Film excluded per References 5, 12 and 13.
	Miscellaneous Particulate (ft^3) - Unit 1	1.5		Foam and Film excluded per References 5, 12 and 13.
	Miscellaneous Particulate (ft^3) - Unit 2	2.99		Foam and Film excluded per References 5, 12 and 13.
Latent Debris	Latent Fiber (ft^3)	9.4		For conservatism, when calculating the volume of latent fiber, the density for Nukon (low density) will be used. *Mass of Latent Fiber = 22.5 lbm* *Density of Nukon = 2.4 lb/ft^3 [Reference 8Vol. 1 Table 4-1]* (22.5 lbm latent fiber / 2.4 lbm/ft^3 = 9.4 ft^3)
	Latent Particulate (ft^3)	18.2		For conservatism, when calculating the volume of latent particulate, the density for Asbestos(lower density than CalSil) will be used. *Mass of Latent Particulate = 127.5 lbm* *Density of Asbestos = 7-10 lb/ft^3 [Reference 8Vol. 1 Table 4-1]* (127.5 lbm latent particulate / 7 lbm/ft^3 = 18.2 ft^3)
Total Additional Debris (Miscellaneous + Latent)	Total Additional Fiber (ft^3) - Unit 1	47.6		Miscellaneous Fiber (ft^3) - Unit 1 + Latent Fiber (ft^3)
	Total Additional Fiber (ft^3) - Unit 2	14.8		Miscellaneous Fiber (ft^3) - Unit 2 + Latent Fiber (ft^3)
	Total Additional Particulate (ft^3) - Unit 1	19.7		Miscellaneous Particulate (ft^3) - Unit 1 + Latent Particulate (ft^3)
	Total Additional Particulate (ft^3) - Unit 2	21.2		Miscellaneous Particulate (ft^3) - Unit 2 + Latent Particulate (ft^3)

A.2 Primary Evaluation Inputs Post-Accident – Bounding Case Bases[7]

		Additional Spreadsheet Inputs (ft³)											
Class	Material / Parameter	Unit 1 Case 1	Unit 1 Case 2	Unit 1 Case 3	Unit 1 Case 4	Unit 1 Case 5	Unit 2 Case 1	Unit 2 Case 2	Unit 2 Case 3	Unit 2 Case 4	Unit 2 Case 5	Unit 2 Case 6	Unit 2 Case 7
Calcium Silicate	CalSil Insulation	**113.05**	110.5	59.53	63.57	89.36	88.46	**122.72**	83.87	83.87	83.87	5.6	111.84
	Asbestos Insulation	**296.74**	275.37	160.81	159.7	296.74	116.07	**116.07**	68.63	80.72	116.07	2.37	116.07
E-glass	Fiberglass Insulation	179.38	125.87	78.02	98.75	**181.4**	107.48	90.57	53.45	53.45	**114.7**	53.7	107.35
	NUKON	**0**	0	0	0	0	1001.1	849.5	422.14	566.25	**1046.65**	0	937.77
	Temp-Mat	**23.44**	20.61	7.3	11.82	23.44	89.28	**99.57**	20	29.48	89.42	0	89.77
Mineral Wool	Min-Wool	203.11	0	0	0	**218.99**	267.21	**323.2**	130.49	18.37	311.3	0	291.43

		BASE CASES Additional Spreadsheet Inputs (ft³)			
Class	Material / Parameter	Unit 1 Case 1	Unit 1 Case 5	Unit 2 Case 2	Unit 2 Case 5
Calcium Silicate	CalSil Insulation	**113.05**		**122.72**	
	Asbestos Insulation	**296.74**		**116.07**	
E-glass	Fiberglass Insulation		**181.4**		**114.7**
	NUKON	**0**			**1046.65**
	Temp-Mat	**23.44**		**99.57**	
Mineral Wool	Min-Wool		**218.99**	**323.2**	

		BASE CASES Additional Spreadsheet Inputs (ft³)			
Class	Material / Parameter	Unit 1		Unit 2	
Calcium Silicate	CalSil Insulation	113.05	Case 1	122.72	Case 2
	Asbestos Insulation	296.74	Case 1	116.07	Case 2
E-glass	Fiberglass Insulation	181.4	Case 5	114.7	Case 5
	NUKON	0	Case 1	1046.65	Case 5
	Temp-Mat	23.44	Case 1	99.57	Case 2
Mineral Wool	Min-Wool	218.99	Case 5	323.2	Case 2

[7] This table includes Debris Generation inputs taken directly from Reference 5 (latent or miscellaneous debris volumes were not added). However, Unit 1 and 2 Debris Generation Quantities applied to spreadsheet evaluations *do* include applicable latent and miscellaneous debris additions, as applied to the CalSil and Fiberglass cell inputs (these additional quantities were added in Appendix A.1 for Bounding Cases and A.3/A.4 for Debris Generation Cases)..

A.3 Unit 1 Debris Generation Case Inputs – All Cases [5][8]

Class	Material / Parameter	Additional Spreadsheet Inputs (ft³) Unit 1 Case 1	Unit 1 Case 2	Unit 1 Case 3	Unit 1 Case 4	Unit 1 Case 5
Calcium Silicate	CalSil Insulation	132.75	130.2	79.23	83.27	109.06
	Asbestos Insulation	296.74	275.37	160.81	159.7	296.74
E-glass	Fiberglass Insulation	226.98	173.47	125.62	146.35	229
	NUKON	0	0	0	0	0
	Temp-Mat	23.44	20.61	7.3	11.82	23.44
Mineral Wool	Min-Wool	203.11	0	0	0	218.99

A.4 Unit 2 Debris Generation Case Inputs – All Cases [5][9]

Class	Material / Parameter	*Additional Spreadsheet Inputs (ft³)* Unit 2 Case 1	Unit 2 Case 2	Unit 2 Case 3	Unit 2 Case 4	Unit 2 Case 5	Unit 2 Case 6	Unit 2 Case 7
Calcium Silicate	CalSil Insulation	109.65	143.91	105.06	105.06	105.06	26.69	133.03
	Asbestos Insulation	116.07	116.07	68.63	80.72	116.07	2.37	116.07
E-glass	Fiberglass Insulation	122.28	105.37	68.25	68.25	129.5	68.5	122.15
	NUKON	1001.1	849.5	422.14	566.25	1046.65	0	937.77
	Temp-Mat	89.28	99.57	20	29.48	89.42	0	89.77
Mineral Wool	Min-Wool	267.21	323.2	130.49	18.37	311.3	0	291.43

[8] Unit 1 Debris Generation Quantities applied to spreadsheet include applicable latent and miscellaneous debris additions, as applied to the CalSil and Fiberglass cell inputs (see Assumptions). These additions are included in the tables above.

[9] Unit 2 Debris Generation Quantities applied to spreadsheet include applicable latent and miscellaneous debris additions, as applied to the CalSil and Fiberglass cell inputs (see Assumptions and Appendix A). These additions are included in the tables above.

A.5 Material Specific Density Values

Point Beach List of Inputs - Material / Parameter Densities

Class	Material / Parameter	Additional Spreadsheet Inputs (lbm/ft^3)
Coolant	Sump Pool Density	62.4 (lbm/ft^3) [per Reference 5]
Metallic Aluminum	Aluminum Submerged	
	Aluminum Not-Submerged	
Calcium Silicate	CalSil Insulation	14.5 (lbm/ft^3) [Reference 8 Table 4-1 (as-fabricated)]
	Asbestos Insulation	10 (lbm/ft^3) [Reference 8 Table 4-1 (as-fabricated)]
	Kaylo Insulation	
	Unibestos Insulation	
E-glass	Fiberglass Insulation	3.3 (lbm/ft^3) [Reference 8 Table 4-1 (as-fabricated)]
	NUKON	2.4 (lbm/ft^3) [Reference 8 Table 4-1 (as-fabricated)]
	Temp-Mat	11.8 (lbm/ft^3) [Reference 8 Table 4-1 (as-fabricated)]
	Thermal Wrap	
Silica Powder	Microtherm	
	Min-K	
Mineral Wool	Min-Wool	10 (lbm/ft^3) [Reference 8 Table 4-1 (General: as-fabricated)]
	Rock Wool	
Aluminum Silicate	Cerablanket	
	FiberFrax Durablanket	
	Kaowool	
	Mat-Ceramic	
	Mineral Fiber	
	PAROC Mineral Wool	
Interam	Interam	

A.6 **Temperature & pH Transient Profile –** Sump Recirculation @ 27 minutes, Spray Recirculation @ 77 minutes

Point Beach List of Inputs - *Temperature & pH Profiles*
Spray Recirculation at 77 minutes

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Steam or Spray pH	Containment Temp. (°F)	
6	0	0	0	9.5	286	10	286	Start of Spray - 0 seconds (Reference 5)
30	0.5	0	0	9.5	286	10	286	
60	1.0	0	0	9.5	286	10	286	
120	2	0	0	9.5	286	10	286	
180	3	0	0	9.5	286	10	286	
200	3	0	0	9.5	286	10	286	
400	7	0	0	9.5	286	10	286	
600	10	0	0	9.5	286	10	286	
800	13	0	0	9.5	286	10	286	
1000	17	0	0	9.5	286	10	286	
1200	20	0	0	9.5	284	10	286	
1400	23	0	0	9.5	282	10	286	
1600	27	0	0	9.5	281	10	286	Start of Sump Recirculation to Core - 27 minutes (Reference 5)
1800	30	1	0	9.5	279	10	286	
3200	53	1	0	9.5	273	10	274	
4600	77	1	0	9.5	269	10	266	Start of Spray Recirculation - 77 minutes (Reference 5)
6000	100	2	0	9.5	266	9.5	261	Assumed Initation of Sump Mixing
7400	123	2	0	9.5	263	9.5	256	
8800	147	2	0	9.5	261	9.5	252	
10200	170	3	0	9.5	259	9.5	250	
11600	193	3	0	9.5	255	9.5	250	
13000	217	4	0	9.5	252	9.5	250	
21600	360	6	0	9.5	249	9.5	250	End of Spray Injection - 6 hours
46400	773	13	1	9.5	213			
86400	1440	24	1	9.5	194			
172800	2880	48	2	9.5	182			
259200	4320	72	3	9.5	176			
345600	5760	96	4	9.5	171			
432000	7200	120	5	9.5	168			
864000	14400	240	10	9.5	157			
1296000	21600	360	15	9.5	151			
1728000	28800	480	20	9.5	147			
2160000	36000	600	25	9.5	143			
2592000	43200	720	30	9.5	141			

A.7 Temperature & pH Transient Profile – Sump Recirculation @ 60 minutes, Spray Recirculation @ 100 minutes

Point Beach List of Inputs - *Temperature & pH Profiles*
Spray Recirculation at 100 minutes

Time (sec)	min.	hr.	days	Sump pH	Sump Temp. (°F)	Steam or Spray pH	Containment Temp. (°F)	
6	0	0	0	9.5	286	10	286	Start of Spray - 0 seconds (Reference 5)
30	0.5	0	0	9.5	286	10	286	
60	1.0	0	0	9.5	286	10	286	
120	2	0	0	9.5	286	10	286	
180	3	0	0	9.5	286	10	286	
200	3	0	0	9.5	286	10	286	
400	7	0	0	9.5	286	10	286	
600	10	0	0	9.5	286	10	286	
800	13	0	0	9.5	286	10	286	
1000	17	0	0	9.5	286	10	286	
1200	20	0	0	9.5	284	10	286	
1400	23	0	0	9.5	282	10	286	
1600	27	0	0	9.5	281	10	286	
1800	30	1	0	9.5	279	10	286	
3200	53	1	0	9.5	273	10	274	
4600	77	1	0	9.5	269	10	266	Start of Sump Recirculation to Core - 60 minutes (Reference 5)
6000	100	2	0	9.5	266	10	261	Start of Spray Recirculation - 100 minutes
7400	123	2	0	9.5	263	9.5	256	Assumed Initation of Sump Mixing
8800	147	2	0	9.5	261	9.5	252	
10200	170	3	0	9.5	259	9.5	250	
11600	193	3	0	9.5	255	9.5	250	
13000	217	4	0	9.5	252	9.5	250	
21600	360	6	0	9.5	249	9.5	250	End of Spray Injection - 6 hours
46400	773	13	1	9.5	213			
86400	1440	24	1	9.5	194			
172800	2880	48	2	9.5	182			
259200	4320	72	3	9.5	176			
345600	5760	96	4	9.5	171			
432000	7200	120	5	9.5	168			
864000	14400	240	10	9.5	157			
1296000	21600	360	15	9.5	151			
1728000	28800	480	20	9.5	147			
2160000	36000	600	25	9.5	143			
2592000	43200	720	30	9.5	141			

A.8 Temperature & pH Transient Profile – Sump Recirculation @ 120 minutes, Spray Recirculation @ 123 minutes

Point Beach List of Inputs - *Temperature & pH Profiles*
Spray Recirculation at 123 minutes

Time (sec)	min	hr	days	Sump pH	Sump Temp. (°F)	Steam or Spray pH	Containment Temp. (°F)	
6	0	0	0	9.5	286	10	286	Start of Spray 0 seconds. (Reference 5)
30	0.5	0	0	9.5	286	10	286	
60	1.0	0	0	9.5	286	10	286	
120	2	0	0	9.5	286	10	286	
180	3	0	0	9.5	286	10	286	
200	3	0	0	9.5	286	10	286	
400	7	0	0	9.5	286	10	286	
600	10	0	0	9.5	286	10	286	
800	13	0	0	9.5	286	10	286	
1000	17	0	0	9.5	286	10	286	
1200	20	0	0	9.5	284	10	286	
1400	23	0	0	9.5	282	10	286	
1600	27	0	0	9.5	281	10	286	
1800	30	1	0	9.5	279	10	286	
3200	53	1	0	9.5	273	10	274	
4600	77	1	0	9.5	269	10	266	
6000	100	2	0	9.5	266	10	261	
7400	123	2	0	9.5	263	10	256	Start of Spray Recirculation 123 minutes
8800	147	2	0	9.5	261	9.5	252	Assumed Initation of Sump Mixing
10200	170	3	0	9.5	259	9.5	250	
11600	193	3	0	9.5	255	9.5	250	
13000	217	4	0	9.5	252	9.5	250	
21600	360	6	0	9.5	249	9.5	250	End of Spray Injection 6 hours
46400	773	13	1	9.5	213			
86400	1440	24	1	9.5	194			
172800	2880	48	2	9.5	182			
259200	4320	72	3	9.5	176			
345600	5760	96	4	9.5	171			
432000	7200	120	5	9.5	168			
864000	14400	240	10	9.5	157			
1296000	21600	360	15	9.5	151			
1728000	28800	480	20	9.5	147			
2160000	36000	600	25	9.5	143			
2592000	43200	720	30	9.5	141			

APPENDIX L: CASE 2.5 – SUPPLEMENTAL CASE: MAX PH, MAX SUMP VOLUME, MIXED, SUMP RECIRC @ 120 MINUTES, SPRAY RECIRC @ 123 MINUTES

L.1 Elemental Releases and Precipitation – Case 2.5

Interval Duration (min)	Start of Interval (hrs)	End of Interval (hrs)	Average Interval pH	Average Temp (F)	Ca Release (kg)	Si Release (kg)	Al Release (kg)	$NaAlSi_3O_8$ Precipitate (kg)	AlOOH Precipitate (kg)	$Ca_3(PO_4)_2$ Precipitate (kg)
0.4	0.00	0.0	9.6	286	0.0544	0.7706	0.0965	0.938	0.000	0.000
0.5	0.01	0.0	9.5	286	0.12	1.73	0.22	2.1	0.0	0.00
1.0	0.02	0.0	9.5	286	0.26	3.65	0.46	4.4	0.0	0.00
1.0	0.03	0.1	9.5	286	0.39	5.57	0.69	6.7	0.0	0.00
0.3	0.05	0.1	9.5	286	0.44	6.20	0.77	7.5	0.0	0.00
3.3	0.06	0.1	9.5	286	0.89	12.56	1.55	15.1	0.0	0.00
3.3	0.11	0.2	9.5	286	1.33	18.85	2.31	22.4	0.0	0.00
3.3	0.17	0.2	9.6	286	1.78	25.07	3.04	29.5	0.0	0.00
3.3	0.22	0.3	9.5	286	2.22	31.22	3.75	36.4	0.0	0.00
3.3	0.28	0.3	9.5	285	2.65	37.20	4.42	42.9	0.0	0.00
3.3	0.33	0.4	9.5	283	3.08	42.90	5.04	49.0	0.0	0.00
3.3	0.39	0.4	9.5	281.5	3.50	48.39	5.62	54.6	0.0	0.00
3.3	0.44	0.5	9.5	280	3.91	53.66	6.16	59.8	0.0	0.00
23.3	0.50	0.9	9.5	276	6.74	87.50	9.43	91.7	0.0	0.00
23.3	0.89	1.3	9.5	271	9.35	116.00	11.73	114.0	0.0	0.00
23.3	1.28	1.7	9.6	267.5	11.78	140.74	13.47	131.0	0.0	0.00
23.3	1.67	2.1	9.5	264.5	14.06	162.45	14.84	144.3	0.0	0.00
23.3	2.06	2.4	9.5	262	16.20	181.71	15.88	154.4	0.0	0.00
23.3	2.44	2.8	9.5	260	17.21	190.05	16.09	156.4	0.0	0.00
23.3	2.83	3.2	9.5	257	18.07	197.01	16.29	158.3	0.0	0.00
23.3	3.22	3.6	9.5	253.5	18.81	202.67	16.48	160.2	0.0	0.00
143.3	3.61	6.0	9.5	250.5	22.63	231.11	17.69	171.9	0.0	0.00
413.3	6.00	12.9	9.5	231	23.69	233.61	17.87	173.7	0.0	0.00
666.7	12.89	24.0	9.5	203.5	23.69	242.91	18.02	175.1	0.0	0.00
1440.0	24.00	48.0	9.5	188	32.17	261.70	18.21	177.0	0.0	0.00
1440.0	48.00	72.0	9.5	179	37.03	276.89	18.36	178.4	0.0	0.00
1440.0	72.00	96.0	9.6	173.5	40.99	289.76	18.48	179.6	0.0	0.00
1440.0	96.00	120.0	9.5	169.5	44.22	300.98	18.58	180.6	0.0	0.00
7200.0	120.00	240.0	9.5	162.5	83.34	351.84	19.00	184.7	0.0	0.00
7200.0	240.00	360.0	9.5	154	83.35	380.83	19.30	187.6	0.0	0.00
7200.0	360.00	480.0	9.5	149	83.35	401.22	19.56	190.1	0.0	0.00
7200.0	480.00	600.0	9.5	145	83.36	417.22	19.78	192.2	0.0	0.00
7200.0	600.00	720.0	9.5	142	83.37	430.32	19.97	**194.1**	**0.0**	**0.00**

Case 2.5 Supplemental Analysis

Maximum Sump Volume =	43317	ft^3
$NaAlSi_3O_8$ Precipitate Mass =	194.119	kg
AlOOH Precipitate Mass =	0.000	kg
$Ca_3(PO_4)_2$ Precipitate Mass =	0.000	kg
Total Precipitate Mass =	194.119	kg