10 CFR 50.54(f)

Progress Energy

Serial: RNP-RA/10-0007

MAR 30 2010

United States Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
Rockville, Maryland 20852

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261/LICENSE NO. DPR-23

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION PERTAINING TO NRC GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS"

Ladies and Gentlemen:

By letter dated December 3, 2009, a request for additional information (RAI) regarding the H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2, response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," was provided by the NRC.

Attachment I to this letter provides an Affirmation in accordance with the provisions of Section 182a of the Atomic Energy Act of 1954, as amended, and 10 CFR 50.54(f).

Attachment II to this letter provides the response to the RAI.

A commitment is being made pertaining to performance of additional strainer testing. If you have any questions concerning this matter, please contact Mr. Curtis A. Castell, Supervisor – Licensing/Regulatory Programs, at (843) 857-1626.

Sincerely,

Benjamin C. White
Manager – Support Services – Nuclear

Progress Energy Carolinas, Inc.
Robinson Nuclear Plant
3581 West Entrance Road
Hartsville, SC 29550

A116
NRR

BCW/cac

Attachments:

I. Affirmation

II. Response to Request for Additional Information on the Supplemental Response to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors"

c: L. A. Reyes, NRC, Region II
T. J. Orf, NRC, NRR
NRC Resident Inspector

AFFIRMATION

The information contained in letter RNP-RA/10-0007 is true and correct to the best of my information, knowledge, and belief; and the sources of my information are officers, employees, contractors, and agents of Carolina Power and Light Company, also known as Progress Energy Carolinas, Inc. I declare under penalty of perjury that the foregoing is true and correct.

Executed On: 3/30/2010

E. A. McCartney
Site Vice President, HBRSEP, Unit No. 2

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATON ON THE SUPPLEMENTAL RESPONSE TO NRC GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS"

By letter dated December 3, 2009, a request for additional information (RAI) regarding the H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2, response to NRC Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," was provided by the NRC. The following information is provided in response to this RAI.

Debris transport

RAI 1 & RAI 4:

Provide additional information to justify the credit taken for the retention of small fibrous fines and particulate debris in the upper containment and inactive holdup volumes or provide additional basis to demonstrate that the head loss impact of the debris is insignificant.

Response:

The HBRSEP, Unit No. 2, containment is considered to be "highly compartmentalized," which is defined as follows:

> Highly compartmentalized containments are defined as those containments that have distinct robust structures and compartments totally surrounding the major components of the RCS [Reactor Coolant System].

The debris quantity and characteristics for blowdown and washdown transport will be recalculated based on the baseline methodology, as described in the Nuclear Energy Institute's (NEI) Guidance Report 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology." Small fibrous fines and particulate will be distributed with 25% to upper containment, 75% to lower containment, and 100% washdown of all fines in upper containment. The head loss testing will be repeated, using the revised debris quantity and methodology consistent with the guidance provided in the report, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008" (ADAMS Accession No. ML080230038). Therefore, Progress Energy commits to perform additional head loss testing using the revised debris quantity and characteristics. Results of this testing are expected to be submitted by September 30, 2010.

RAI 2:

Provide additional information in light of the discussion below to justify the assumptions of zero percent erosion and zero percent transport of large pieces of fibrous debris.

Response:

Transport of large pieces will be addressed by assuming erosion of the large pieces and including the erosion fines in the head loss test debris mix. Ten percent of the large pieces will be assumed to erode and deposit on the screens as fines. This is considered reasonable and conservative because the fines in the debris bed are expected to add more to the head loss than large pieces.

The debris quantity and characteristics will be recalculated, based on the baseline methodology, as described in the NEI Guidance Report 04-07. As previously stated, the head loss testing will be repeated, using the revised debris quantity and methodology consistent with the guidance provided in the report, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008" (ADAMS Accession No. ML080230038).

Therefore, Progress Energy commits to perform additional head loss testing using the revised debris quantity and characteristics. Results of this testing are expected to be submitted by September 30, 2010.

Head Loss and Vortexing

RAI 5

Provide justification that the debris preparation for the head loss testing resulted in a conservative or prototypic head loss value for limiting plant conditions.

Response:

As previously stated, the head loss testing will be repeated, using the revised debris quantity. The debris preparation and introduction for this testing are expected to be consistent with methods previously determined to be acceptable for this type of testing. Therefore, Progress Energy commits to perform additional head loss testing (including thin bed) using the revised debris quantity and methodology consistent with the guidance provided in the report, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008" (ADAMS Accession No. ML080230038). Results of this testing are expected to be submitted by September 30, 2010.

RAI 7

Provide information that justifies that any agglomeration of debris did not affect head loss test results nonconservatively.

Response:

As previously stated, the head loss testing will be repeated, using the revised debris quantity and methodology consistent with the guidance provided in the report, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008" (ADAMS Accession No. ML080230038). The debris preparation and introduction for this testing are expected to be consistent with methods previously determined to be acceptable for this type of testing. Therefore, Progress Energy commits to perform additional head loss testing using the revised debris quantity and characteristics. Results of this testing are expected to be submitted by September 30, 2010.

RAI 8

Provide an evaluation that shows that any settling that occurred resulted in a negligible effect on head loss test results or that the settling was prototypical or conservative compared to the expected plant conditions.

Response:

As previously stated, the head loss testing will be repeated, using the revised debris quantity. Therefore, Progress Energy commits to perform additional head loss testing using the revised debris quantity and methodology consistent with the guidance provided in the report, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008" (ADAMS Accession No. ML080230038). The debris preparation and introduction for this testing are expected to be consistent with methods previously determined to be acceptable for this type of testing. Results of this testing are expected to be submitted by September 30, 2010.

RAI 10

Provide additional information on the vortex evaluation methodology so that the staff may fully evaluate the ability of the strainer system to prevent the formation of vortices.

Response:

In the discussion below, the average velocity through the perforated plate of an individual top hat strainer is referred to as the top hat approach velocity. The average velocity through the perforated plates of the array of individual top hat strainers forming the sump screen is referred to as the screen approach velocity. It is noted that the top hat tested for vortexing was slightly shorter than the size use in the HBRSEP, Unit No. 2, strainer.

Vortex testing was conducted on horizontal, single top hat modules, with perforated plate diameters of 8 inches and 6 inches, a perforated plate surface area of 9.2 square feet and a cross-sectional flow area through the strainer base plate of 0.132 square feet. The water level was set to 3 inches above the top of the perforated plate of the strainers, which is comparable to the minimum design water level. The average top hat approach velocity was increased in this testing from 0.01 feet/second to 0.03 feet/second with no air-entraining vortices detected. Testing was also conducted from 0.04 feet/second to 0.09 feet/second showing that air-entraining vortices could occur at these velocities and were completely eliminated by standard 1.5 inches-thick floor grating installed flush with the surface of the water.

Based on testing described above, two correlations were derived for flow velocity through the individual top hat base plate and the onset of vortexing. Since the vortexing is driven by the velocity through the base plate of the top hat – the area of greatest constriction, greatest fluid acceleration, and therefore lowest pressure in the strainer module – the highest flow velocity through the base plate for which no vortexing occurred was considered as a limiting condition and both correlations were based on the limiting base plate velocity.

One correlation was made by directly relating the limiting base plate velocity to the top hat approach velocity based on the ratio of base plate to perforated plate flow areas. The other correlation determined the limiting Froude number based on the limiting velocity through the top hat base plate and submergence below the water surface. Both correlations were used to calculate the maximum top hat approach velocity that can be sustained without vortexing for the HBRSEP, Unit No. 2, top hats. The lower of the two calculated velocities was used. The testing was conducted on "single" 36-inch top hats and the installed top hats are of the "double" design, i.e. similar to two concentric single top hats that are either 48-inch or 54-inch. The methodology called for determination of the limiting top hat approach velocity based on only the outer annulus base plate and perforated plate areas. The calculated limiting top hat approach velocity is inversely proportional to the perforated plate area. Conservatively, only the outer annulus base plate flow area and the entire perforated plate areas of both the inner and outer annulus were used in determination of the limiting maximum top hat approach velocity. The limiting maximum top hat approach velocity to prevent the onset of vortexing for the strainer was determined to be 0.0115 feet/second.

The maximum normalized screen approach velocity with the strainer fully loaded with debris is 0.002 feet/second. This is well below the limiting maximum top hat approach velocity of 0.0115 feet/second. Therefore, air entrainment due to vortexing is not expected when the strainer is fully loaded and top hat approach velocities converge to normalized screen approach velocities.

The screens are arranged on a horizontal plenum mounted on the floor with top hat strainers arranged in sets of two (one on either side of the plenum). In addition, there are two plenums, one located inside the crane wall and one located outside the crane wall. The maximum expected top hat approach velocity with clean screens was calculated as 0.017 feet/second at the first set of top hats nearest the sump (i.e., nearest the pump suction) located inside the crane wall.

The top hat approach velocity at the first set of top hats is above the limiting maximum top hat approach velocity of 0.0115 feet/second. The high top hat approach velocity indicates the potential for vortexing without the use of vortex suppressors. The top hat approach velocities drop off very quickly and the third set of top hats has a maximum top hat approach velocity of only 0.009 feet/second, which is approximately 21% less than the limiting maximum top hat approach velocity. The maximum expected top hat approach velocity, at the first set of top hats, outside the crane wall is 10% less than the limiting top hat approach velocity. The remaining top hats inside and outside the crane wall are well below the limiting top hat approach velocity.

To eliminate the concern over air core vortices, vortex suppressors are installed over all of the top hats outside the crane wall and over the first eight sets of top hats inside the crane wall. Inside the crane wall, the eighth set of top hats have a maximum expected top hat approach velocity of only 0.004 feet/second providing a margin to vortexing, without vortex suppressors, of more than a factor of 2.8. Testing showed the vortex suppressors eliminated vortexing with top hat velocities up to the highest tested velocity of 0.09 feet/second, or approximately 5 times the highest top hat approach velocity of 0.017 feet/second.

RAI 11

Provide the size distribution of the particulate insulation surrogate used during testing.

Response:

As previously stated, the head loss testing will be repeated, using the revised debris quantity. Therefore, Progress Energy commits to perform additional head loss testing using the revised debris quantity and methodology consistent with the guidance provided in the report, "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008" (ADAMS Accession No. ML080230038). Particulate insulations and insulation surrogates used during testing are expected to be in powder form, which is consistent with the original testing. Size distribution for particulate insulation and the insulation surrogates used during the repeat testing will be provided with the test results.

Powdered Calcium Silicate was used in the previous testing and is expected to be used as the surrogate for Cal-Sil insulation material. The other surrogates are expected to be consistent with the information provided in the RAI response dated December 17, 2008.

RAI 14

Provide justification that the debris bed head loss was not limited due to bed shifting or provide an evaluation based on the head loss that could occur should the head loss be limited as described above.

Response:

To address the potential for bed shifting, it is expected the chemical effects head loss will not be temperature corrected and the net positive suction head (NPSH) margin will credit the time delay of chemical precipitate formation based on bench top test results as previously described in the December 17, 2008, RAI response letter. This is similar to the testing and approach used by other utilities. The time delay will allow crediting an additional 10 feet or more of NPSH available, which will address the bed shifting issue without adversely impacting pump NPSH margin.

The chemical debris load was assumed to instantaneously form on the screens. The debris actually takes time to form, during which the sump will cool to subcooled conditions, i.e. cool to where the vapor pressure is below the minimum pre-accident containment pressure.

Bench top testing was conducted to determine the timeline for chemical formation in the sump. The tests consisted of a series of temperature controlled and gently stirred beakers. Each beaker was filled with deionized water buffered to a target pH representative of the emergency core cooling system (ECCS) sump along with insulation and structural materials found in the containment that may contribute to the formation of chemical precipitates. The amounts of materials were scaled to be representative of the containment sump. Five tests with three replicates of each were conducted. The five tests consisted of a baseline test, tests with reduced levels of Cal-Sil, tests with higher water pH, and a test with a 20% increase in aluminum. Temperatures were controlled over time to mimic post-loss of coolant accident (LOCA) temperature. The beakers were visually monitored for signs of precipitate formation for 3 days. Also, frequent samples were taken for inductively coupled plasma-atomic emission (ICP) analysis.

At the end of the test, material samples were collected from the beakers and analyzed by scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS) for the presence of precipitates. The surface of the insulation fibers exhibited no signs of coatings or adherence of bulk precipitates and the microstructure and EDS spectra of the Cal-Sil samples appeared identical to the un-tested Cal-Sil, indicating no precipitation. EDS spectra of the aluminum samples indicated some areas of corrosion and other areas of surface passivation. Solution transparency, ion concentrations, and debris microstructure provide evidence that minimal or no precipitation will occur in a post-LOCA environment at HBRSEP, Unit No. 2, for temperatures above 110°F.

Based on the post-LOCA containment analysis, the sump pool temperature will be less than 190°F after 11.1 hours. At temperatures below 209°F the water will be subcooled compared to the saturation temperature at the minimum pre-accident containment pressure. At 190°F, the corresponding reduction in vapor pressure is 4.5 psi or 10.4 feet of water below the minimum pre-accident containment pressure. A 10.4 feet decrease in vapor pressure will more than offset the 7.4 feet increase (to 10 feet) of head loss through the strainer. The net result is expected to be an increase in the debris plus chemical effects NPSH margin of 3.0 feet or more over the previous analysis without adjusting the measured head loss for temperature. In addition, the design differential pressure for the screens is 15 feet. Therefore, allowing the head loss to increase to 10 feet will not challenge the structural integrity of the screens.

The revised analysis and testing is expected to be based on chemical precipitant formation to occur at a sump temperature of 140°F based on bench top testing for HBRSEP, Unit No. 2.

<u>Structural analysis</u>

<u>RAI 17</u>

Provide an explicit and detailed summary of the quantitative results of the structural design qualification of the different components of the replacement sump strainer structural assembly (including trash racks, if any) under design loads and load combinations; and their comparison to the design code acceptance criteria. This information should include actual stresses, forces, displacements, etc. (as applicable), the component material type, the corresponding code allowables, and interaction ratios for the limiting members of the various structural components of the replacement strainer assembly. Additionally, provide a more detailed list of all the components that were analyzed for structural adequacy, including a description of the components.

Response:

The modified recirculation sump screen assemblies and structures were structurally analyzed and found to meet the design requirements given in the Updated Final Safety Analysis Report (UFSAR) for HBRSEP, Unit No. 2. The load combinations used in this analysis are the same as already defined for structures in safety-related applications for HBRSEP, Unit No. 2. Analyses and evaluations determined that trash racks were not required for the new ECCS sump strainer and structure design.

Structural evaluations were performed for the new horizontally oriented sump strainer top hats, sump plenum modules, and vortex suppression personnel walkway structures over the sump strainers and plenum. The plenum and vortex suppression personnel walkway structures are anchored on the bottom level (Elevation 228 feet) of the Containment Building. Analyses were performed using a combination of manual calculations and finite-element analysis using GTSTRUDL computer codes that are typically used to qualify Safety-Related structures.

The evaluations followed the requirements of American Institute of Steel Constructions (AISC) Specification for design, fabrication, and erection of structural steel for buildings, contained in the AISC Manual of Steel Construction (8th and 9th editions), plant-specific design specifications, and design basis documents. The AISC Manual does not provide allowable limits for evaluation of stainless steel materials at elevated temperatures. Therefore, American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code Section III or American Society for Testing and Materials (ASTM) Standards, which do list material property values for stainless steel at various elevated temperatures, were used to evaluate stainless steel materials.

The stainless steel weld filler metal was conservatively assumed to have a minimum tensile strength of 70 ksi. The sump strainer top hats, plenum, sump box, and vortex suppression personnel walkway structures were conservatively qualified for faulted loads using the lower normal allowable values. Anchor bolt allowable values were based on a minimum factor of safety of 4.

The strainers, plenum, and vortex suppression personnel walkway structures were designed for the following loads:

- Deadweight Loads –Deadweight load of the top hat component materials, the strainers, plenum components and structural materials, and vortex suppression personnel walkway structures was included.
- Seismic Loads – The Design Basis Earthquake (DBE) and the Safe Shutdown Earthquake (SSE) loads were developed from response spectra curves that envelop the response spectra curves for HBRSEP, Unit No. 2. Peak accelerations and response spectra for the appropriate elevation in the containment building with a 2% critical damping were used in the analyses. Use of the 2% damping was conservative as compared with the 2.5% described in the HBRSEP, Unit No. 2, UFSAR for "bolted" steel structures. Seismic loads included the mass due to submergence of the strainer system and structures during post-LOCA conditions.
- Differential Pressure Loads – Differential pressure loading of 7 psid experienced by the strainers and plenum structures and components due to debris accumulation and clogging of the strainer media during post-LOCA system operation is considered on external surfaces of the strainer structures.
- Live Loads – Live load of 100 psf was applied to the Vortex Suppression Personnel walkway structure that is over, but not structurally connected to the strainers and plenum.
- Thermal Loads – Thermal expansion was considered in the design and layout of the strainer assemblies. The strainers themselves are free to expand in the axial, horizontal direction. Slotted bolt holes, gaps, and clearances were utilized in the design of connections and structures to accommodate thermal growth. The design temperature for the strainers was conservatively set at 300°F as compared to the containment structural design temperature of 263°F.

The loads were combined as follows:

Top hat strainers:
Deadweight + Seismic (including hydro dynamic mass) + Differential Pressure $\leq S_y$
(Sy represents minimum yield of material at 300 degrees F.)

Sump plenums:
Load case No.1 - Deadweight $\leq F_s$ (Normal)
Load case No. 5 to 8 Deadweight + Earthquake (SSE) $\leq 1.5F_s$ (Faulted)
Load case No.10 to 17 Deadweight + Earthquake (SSE) + Differential Pressure $\leq 1.5F_s$ (Faulted)
Note: Load case No. 14 to 17 includes differential pressure
For evaluation of steel plates and shapes, including welds, the term Fs represents the definition of allowable stress in steel per AISC Specification for Structural Buildings

Vortex Suppressor Personnel Walkway:
Load case No. 1 - Deadweight $\leq F_s$ (Normal)
Load case No. 2 - Grating Deadweight $\leq F_s$ (Normal)
Load case No. 3 - Live Load $\leq F_s$ (Normal)
Load case No. 4 and 5 - Earthquake (SSE) $\leq 1.5F_s$ (Faulted)

Load case No. 6 to 14 various combinations of Deadweight, Grating Deadweight), Live Load, and Earthquake (SSE) $\leq$ 1.5F_s (Faulted)

The results of the analysis are provided as follows:

<u>Sump Strainer Top Hats</u>:

- Perforated Tubes
  Bending Stress = 830 psi < 4,509 psi - Acceptable
  Axial Stress = 69 psi Negligible - Acceptable
  Hoop Stress = 560 psi < 4,509 psi - Acceptable
- 3/8 inch diameter Studs:
  Tension = 667.5 lbs < 1546 lbs - Acceptable
  Shear= 117.9 lbs < 573 lbs - Acceptable
  Interaction ratio = 0.23 < 1.0 - Acceptable
- Baseplate:
  Bending Stress = 9,079 psi < 16,875 psi -Acceptable
- Welding:
  1/16 inch fillet between perforated tube and bottom flange;
  Load = 127.47lbs/in < 563lbs/in – Acceptable
  Base metal
  1/16 inch fillet between perforated tube and cover plate;
  Load = 70.16 lbs/in < 563 lbs/in – Acceptable
  Base metal weld allowable is limiting

<u>Sump Plenum Modules</u>:

- Top plate of typical sump plenum module 15 inches x 15 inches x 62 inches
  Bending Stress= 10,000 psi < 16,875 psi - Acceptable
  Interaction Ratio = 0.59 < 1.0 - Acceptable
- Baseplates (Not at closed ends of plenum):
  ¾ inch x 16 inches x 23 inches with1/2 inch diameter Hilti Kwik Bolt 3 anchor bolts (minimum embedment of 2-1/4 inches)
  Maximum Plate Stress (bending) = 4,546 psi < 16,875 psi - Acceptable
  Typical maximum anchor bolt interaction ratio is 0.39 < 1.0 - Acceptable
  For Module AA baseplate, field interferences required moving vertical post attachments closer together than typical, resulting in additional support loads and an anchor bolt interaction ratio of 0.54 < 1.0- Acceptable
- Baseplate at closed end of plenum:
  ¾ inch x 22 inches x 22 inches with ¾ inch diameter Hilti Kwik Bolt 3 anchor bolts (minimum embedment of 6-1/2 inches)
  Maximum Plate Stress (bending) = 13,023 psi < 16,875 psi - Acceptable
  Maximum anchor bolt interaction is 0.43 < 1.0 - Acceptable
- Alternate Support Detail (baseplates not at closed ends of plenum):
  ¾ inch x 10 inches x 15 inches with 3/8 inch diameter Hilti Kwik Bolt 3 anchor bolts (minimum embedment of 1 - 5/8 inches)

Maximum Plate Stress (bending) = 1,760 psi < 16,875 psi - Acceptable
Maximum anchor bolt interaction is 0.26 < 1.0

- Alternate Support Detail (for baseplate at closed ends of plenum):
  ¾ inch x 10 inches x 15 inches with 3/8 inch diameter Hilti Kwik Bolt 3 anchor bolts (minimum embedment of 1-5/8 inches)
  Maximum Plate Stress (bending) = 7,221 psi < 16,875 psi - Acceptable
  Maximum anchor bolt interaction ratio is 0.93 < 1.0 - Acceptable
- Bolted connections between bottom of plenum and ½ inch x 10 inches x 15 inches plate
  3/8 inch A193 Gr.B8 CL 2 bolts
  Interaction ratio = 0.27 < 1.0 - Acceptable
  ½ inch plate, Bending Stress = 5,704 < 16,875 psi - Acceptable
- Weld between ¾ inch plate and tube steel 4 inches x 4 inches x ¼ inch - Acceptable
  Interaction ratio for weld metal stress = 0.445 < 1.0 - Acceptable
  Interaction ratio for base metal shear = 0.734 < 1.0 - Acceptable
- Angle 2 inches x 2 inches x ¼ inch and 3/8 inch Hilti Kwik Bolt 3 (minimum embedment of 1-5/8 inches)
  Bending stress = 9,284 psi < 13,500 psi - Acceptable
  Axial = 340 psi - Negligible
  Maximum anchor bolt interaction = 0.80 < 1.0
  Tube steel 4 inches x 4 inches x 3/8 inch, Tube steel 4 inches x 4 inches x ¼ inch
  Maximum Interaction Ratio = 0.059 < 1.0 - Acceptable
- ½ inch diameter through bolt connection of Tube Steel 4 inches x 4 inches x ¼ inch and Angle 2 inches x 2 inches x ¼ inch
  Shear = 1,258 lbs < 1,719 lbs allowable - Acceptable
  Tension = 600 lbs < 4,691 lbs allowable - Acceptable
- Fillet weld of Modules to baseplates
  Interaction Ratio for weld metal stress = 0.034 < 1.0 - Acceptable
  Interaction Ratio for base metal shear = 0.057 < 1.0 – Acceptable

All members are adequate by comparison to normal AISC allowables.

- Plenum modules directly anchored to floor with 3/8 inch Hilti Kwik Bolt 3 with minimum embedment 1-5/8 inches

- Maximum anchor bolt interaction ratio = 0.68 < 1.0 – Acceptable

<u>Vortex Suppressor Personnel Walkway</u>:

- Baseplates:
  Maximum Plate Stress = 1,649.5 psi which provides an interaction of 0.10
  Maximum anchor interaction is 0.39 < 1.0 – Acceptable
- Member Stresses:
  Max. Stress Interaction Ratio:
  For Tube Steel members, maximum stress ratio = 0.555 < 1.0 - Acceptable

For wide flange beam members, maximum stress ratio = 0.706 < 1.0 - Acceptable with exception of some locations where flanges had to be trimmed due to conduit interferences, resulting in bending stress of 18,583 psi < 20,500 psi

For Angle members, maximum stress interaction = 0.889 < 1.0 – Acceptable

For Pipe (leg) members, maximum stress interaction = 0.330 < 1.0 – Acceptable

- Baseplates
  Maximum plate bending Interaction Ratio = 0.25 < 1.0 – Acceptable
  Maximum anchor bolt Interaction Ratio = 0.79 < 1.0 – Acceptable
- Fillet Weld, Tube Steel to baseplate
  Maximum Interaction Ratio for weld metal stress= 0.532 < 1.0 – Acceptable
  Maximum Interaction Ratio for base metal shear=0.878 < 1.0 – Acceptable
- Fillet weld, pipe leg to baseplate
  Maximum Interaction Ratio for weld metal stress=0.225 < 1.0 – Acceptable
  Maximum Interaction Ratio for base metal shear=0.371<1.0 – Acceptable
- Bolted connection between posts and horizontal members
  Pair of ¾ inch plates with four 5/8 inch diameter bolts, A-193, Gr.B8.Cl.2
  Maximum plate stress =11,206 psi < 16,875 psi – Acceptable
  Maximum bolt Interaction Ratio = 0.84 < 1.0 – Acceptable
- Bolted connection between vortex suppressor supporting Angle 4 inches x 4 inches and ½ inch vertical plate
  Pair of 5/8 inch diameter bolts, A-193, Gr.B8 Cl.2 A-479, Type 304
  Maximum bolt interaction= 0.62 < 1.0 – Acceptable
- Bolted connection between 4 inches x 13 inches and Tube Steel 6 inches x 6 inches x 1/4 inch (horizontal beam)
  Pair of ½ inch diameter bolts, A-479, Type 304
  Maximum bolt interaction ratio = 0.50 < 1.0 – Acceptable
- Fillet weld of ½ inch vertical connector plate to Tube Steel 6 inches x 6 inches x 1/4 inch
  Maximum Interaction Ratio for base metal shear stress = 0.396 < 1.0 – Acceptable
  Maximum Interaction Ratio for base metal shear = 0.654 < 1.0 – Acceptable
- ½ inch Connector plate
  Maximum bending stress = 6,515 psi < 16,875 psi – Acceptable
  Maximum shear stress = 1,525 < 9,000 psi – Acceptable

Net Positive Suction Head (NPSH)

RAI 16

Please address whether a single failure of a throttle valve to the open position in post-LOCA scenarios during recirculation where throttling credit is taken would result in increased flows through the residual heat removal (RHR) pump(s) that could result in a loss of net positive suction head margin or emergency core cooling system strainer structural limits being exceeded.

Response:

The valves are throttled only in the alignment of two RHR pumps operating and providing suction to the High Head Safety Injection (SI) pumps. This is not the limiting system alignment for determination of RHR pump NPSH because with two pumps operating, each pump operates at a lower flowrate and with a lower NPSH required than the single pump operation case. The loss of throttling capability in this configuration results in a less limiting condition for determining NPSH than the limiting condition of one pump operating because the additional head loss through the screens resulting from the higher total flowrate is less than the NPSH required improvement resulting from lower individual pump flowrate. The following table provides the baseline limiting case (Case 1) and the cases (Case 2 and 3) of two pump operations with and without throttle valve failure.

Case	Screen Flow (gpm)	Pump Flow (gpm)	Screen Debris and Plenum Head Loss (ft)	Pump NPSHA (ft)	Pump NPSHR (ft)	NPSH Margin (ft)
1 (1 RHR Pump for cold leg recirculation)	3794	3794	5.18	14.78	14.47	0.31
2 (2 RHR Pumps aligned to 2 SI pumps for simultaneous hot and cold leg recirculation)	3142	A: 1560 B: 1582	4.06	A: 17.99 B: 18.04	A: 9.18 B: 9.18	A: 8.81 B: 8.86
3 (2 RHR Pumps aligned to 2 SI pumps for simultaneous hot and cold leg recirculation, throttle valve failed open)	5443	A: 2637 B: 2806	8.45	A: 12.66 B: 12.68	A: 10.03 B: 10.25	A: 2.63 B: 2.43

Incorporating strainer head loss, NPSH margin is 8.8 feet without valve failure and 2.4 feet with a valve failure, for the condition of two RHR pumps operating.

Additionally, the strainers are designed for a differential pressure of 6.5 psi (15 feet). The total head loss across the screen and plenum concurrent with throttle valve failure is 3.5 psi (8.4 feet). Differential pressure across the top hat strainers only, is less. Therefore, structural limits are not challenged as a result of throttle valve failure.