Duke Energy
Carolinas

DUKE ENERGY CAROLINAS, LLC
Catawba Nuclear Station
4800 Concord Road
York, SC 29745

August 13, 2012

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

SUBJECT: Duke Energy Carolinas, LLC (Duke Energy)
Catawba Nuclear Station, Units 1 and 2
Docket Nos. 50-413 and 50-414
Final Responses to NRC Request for Additional Information (RAI) related to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors"

On September 13, 2004, the NRC issued GL 2004-02. The GL requested that all pressurized-water reactor licensees (1) evaluate the adequacy of the emergency sump recirculation function with respect to potentially adverse effects associated with post-accident debris, and (2) implement any plant modifications determined to be necessary.

Duke Energy has been actively engaged in these evaluations, including completion of emergency sump strainer modifications at Catawba. By letter dated March 1, 2005, as supplemented by letters dated September 1, 2005 and June 28, 2006, Duke Energy provided responses to GL 2004-02. Duke Energy has continued to communicate with the NRC both formally and informally on progress to address remaining issues related to strainer qualification. More recently, The Supplemental Responses to GL 2004-02 were formally sent to the NRC by Catawba's submittals dated February 29 and April 30, 2008. From these submittals, the NRC developed plant-specific requests for additional information (RAIs) that were received by Catawba on November 21, 2008.

Duke Energy discussed the Catawba RAIs with the NRC in a public teleconference on September 1, 2009 in order to clarify the path forward regarding prototype strainer testing and several industry-wide issues affecting credited analytical refinements.

In another teleconference with the NRC on June 9, 2010, Duke Energy agreed to provide plant-specific draft RAI responses by September 30, 2010 to assure clear understanding of methodology prior to formal RAI response submittal. The draft RAI responses were submitted for NRC review on September 30, 2010.

The draft responses were discussed in a follow-up teleconference with the NRC on November 1, 2010. As strainer performance testing was still underway at that time, the formal responses to many of the RAIs were unfinished pending the

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test results and documentation. The strainer performance testing was completed in February 2011 and the results certified via report on July 6, 2012.

The purpose of this letter is to provide the formal Generic Letter 2004-02 Supplemental Response RAI responses for Catawba Nuclear Station.

Attachment 1 provides an overview of the Catawba GL 2004-02 resolution path and identifies any changes made to the draft RAI responses submitted on September 30, 2010.

Attachment 2 provides the final RAI responses for Catawba.

Attachment 3 identifies remaining commitments made in support of Catawba GL 2004-02 resolution.

Duke Energy will be working with the NRC Project Manager to arrange a follow-up teleconference to discuss any points of clarification needed on these final RAI responses.

If any questions arise or additional information is needed, please contact Randy Hart at (803) 701-3622.

Very truly yours,

Kelvin Henderson
Site Vice President

Attachments

Kelvin Henderson affirms that he is the person who subscribed his name to the foregoing statement, and that all the matters and facts set forth herein are true and correct to the best of his knowledge.

Kelvin Henderson, Vice President, Catawba Nuclear Station

Subscribed and sworn to me: 8-13-2012
Date

_______________, Notary Public

My commission expires: 6-21-2022
Date

SEAL

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Attachment 1

Preface to Final Catawba Responses
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC Request for Additional Information

August 13, 2012

Preface to Final Catawba Responses
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC Request for Additional Information
August 13, 2012

Since the formal submittal of the Catawba Nuclear Station Generic Letter (GL) 2004-02 Supplemental Responses in the spring of 2008 and the receipt of Requests for Additional Information (RAI) from the NRC in the fall of that year, Duke Energy has been actively engaged with the staff in resolving questions and concerns related to the Emergency Core Cooling System (ECCS) Sump Strainer design and qualification for each station. This interface has led to specific changes in the original approach addressing GL 2004-02 for Catawba, and also to a clearer understanding of the additional actions required for final resolution. In responding to the RAIs, Duke Energy has incorporated the following differences from the original GL 2004-02 approach: Catawba is no longer crediting Zone of Influence (ZOI) refinements for fiberglass insulation associated with WCAP-16710-P "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants."

Catawba has replaced a significant amount of low density fiberglass (LDFG) insulation from the Unit 1 steam generators with reflective metal insulation (RMI). Unit 2 steam generators were previously insulated with RMI and Unit 2 remains bounded by the overall insulation quantities contained in Unit 1.

Catawba submitted a license amendment to the NRC for ECCS Water Management modifications. This LAR reduces the number of required ECCS trains from four to three (2 trains of RHR and one of CS, referred to as "three-train flow" throughout this submittal). The effect of these changes include revisions to post-accident response that reduce recirculation flow rates through the ECCS Sump Strainers, increases post-accident sump pool volume and decreases the predicted volume of transported sump pool debris. This license amendment was approved and the modifications are complete for both Catawba Unit 1 and Unit 2.

ECCS Sump Strainer performance for Catawba was confirmed in 2011 via a prototype Chemical Precipitates Head Loss test, which followed the guidance provided in "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant-Specific Chemical Effect Evaluations", dated March 2008, in conjunction with the methodology described in WCAP-16530-NP, Evaluation of Post-Accident Chemical Effects In containment Sump Fluids to Support GSI-191.

The attached final RAI responses integrate the differences identified above and represent the current Duke Energy understanding and proposed resolution of remaining open issues related to the Catawba GL 2004-02 Supplemental Responses. Catawba discussed the response methodology for each NRC RAI question during a public teleconference with the technical staff on September 1, 2009 to facilitate final response development. The NRC's comments/clarifications on the RAI questions and proposed response methodology received during the public teleconference, provided they were not altered by the changes identified above, were also incorporated.

At the NRC's request, draft RAI responses encompassing the above were submitted for review on September 30, 2010, and a follow-up teleconference conducted on November 1, 2010 to ensure the path to GL 2004-02 closure was understood. With the exception of the then ongoing ECCS Strainer performance testing related RAI questions, the staff provided additional response comments for inclusion in the final RAI responses which have also been incorporated. The testing related issues have been discussed at length with the staff as they have occurred, and the final disposition of these issues is included herein in the appropriate RAI responses.

ECCS Strainer Performance Testing Chronology

NRC technical staff concerns with the Array Test and the 2007 Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation.

In June 2009, a Confirmatory Head Loss test series was performed at Wyle Laboratories by Duke Energy using a newly designed flume and conventional debris (i.e., bounding fiber and particulate loads) to address the debris preparation, debris introduction, debris agglomeration/settling and flow field issues identified by the staff regarding the 2007 Integrated Prototype Test (IPT). NRC staff guidance from March of 2008 as well as input from discussions with the staff were used for the test protocol development for the Confirmatory Head Loss test series. Upon completion of the June 2009 testing, the protocol, debris bed formation and head loss results were discussed with the staff in July 2009, along with photos and videos obtained during the testing. From these conversations, the staff concluded that the methods and protocol being utilized for conventional debris preparation and introduction during the tests met NRC expectations.

In parallel with the Confirmatory Head Loss test series in June 2009, Duke Energy provided a draft white paper to the technical staff entitled "Duke Energy Chemical Effects Testing in Support of GSI-191". This document served as a guide for discussions with the staff on the battery of testing performed by Duke Energy to date in the area of chemical effects, and to address NRC concerns with the effect of potential chemical precipitates. As a result of these discussions, Duke Energy elected to continue head loss testing in the fall of 2009, using the Confirmatory Head Loss test series protocol and test flume along with pre-mixed chemical precipitates in accordance with staff guidance. The fall 2009 testing was identified as the Chemical Precipitates Head Loss test series, which continued into the spring of 2010. The results of this precipitate testing were discussed with the NRC staff in April and May of 2010.

Subsequent to the Chemical Precipitates Head Loss test series, Duke Energy determined that a one-time, long-term test approach utilizing soluble aluminum injection (as opposed to introducing pre-mixed precipitates) would be more representative of the post-LOCA environments predicted in ice condenser containments. Identified as the Confirmatory Integrated Test (CIT), the development of the test protocol followed discussions in June 2010 with the NRC staff, and incorporated previous testing experience with conventional debris preparation, introduction, and transport to facilitate the formation of a uniform debris bed on a prototype strainer array. During the initial phases of the CIT, difficulties were encountered with the test system and the test was abandoned. The difficulties and the plan forward were discussed with the staff in November 2010.

After the CIT was abandoned, Duke Energy determined that the Chemical Precipitates Head Loss test methodology utilized previously would provide a robust long-term design basis position when combined with additional mitigating measures that have been either completed or are underway. These measures include replacing a significant amount of fibrous insulation in Containment with RMI (FIRP modifications), and modifying the plant accident mitigation strategy to include ECCS Water Management methodology. This approach was discussed with the staff in February 2011.

Once the potential effects of these additional mitigating measures were determined, the Chemical Precipitates Head Loss test series was continued with the appropriate refined inputs (reduced ECCS flow and fibrous debris volumes). The testing inputs, methodology and results discussed in this submittal are based on the revised/continued Chemical Precipitates Head Loss test series. The confirmatory testing that took place between the 2007 IPT and the 2011 final testing provided insights on testing methodologies and strainer performance and informed the Chemical Precipitates Head Loss test series, but are not considered tests of record and will not be described further in this submittal.

Preface to Final Catawba Responses
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC Request for Additional Information
August 13, 2012

Changes to the September 30, 2010 Catawba Draft Responses

The following Catawba RAI question responses have been modified from the draft versions submitted to and reviewed by the NRC staff. Other than the responses related to the recently completed ECCS Sump Strainer Performance testing, the changes are editorial and clarification related and result from the enhanced review process associated with the issuance of the formal RAI response. The changes made are identified for convenience.

RAIs 1, 2, 3, 5, 6, 7, 8, 9, 13, 22, 26, 27, 29	Minor editorial changes and clarifying statement changes only.
RAIs 4, 12,	Changed to note the completion of the ECCS Water Management Modifications on Units 1 and 2 at Catawba and the effects on flow.
RAI 10	Clarified lower containment area description, added clarifying information regarding the ice condenser post-accident environment, and added details on Electromark label assumed failures due to dose.
RAI 11, 25	Responses completely revised due to ECCS Sump Strainer performance retesting.
RAI 14	Additional detail on debris preparation was added to this response.
RAI 15,16	Additional detail on creating a test with prototypical debris distribution was added to this response.
RAI 17	Additional detail on pressure-induced effects (boreholes) was added to this response
RAI 18	Additional detail on scaling parameters concerning debris quantities and strainer velocities was added to this response.
RAI 19, 24	This response was updated due to NRC technical staff concerns with the Array and Integrated Prototype Tests. RAIs 14 and 15 cover the new information in detail.
RAI 20	This response was revised due to retesting with new parameters that reflected ECCS Water management Modifications and Insulation removal in Unit 1 of Catawba.
RAI 21	This response was updated due to NRC technical staff concerns with the Array and Integrated Prototype Tests. RAI 25 provides the details of this response.
RAI 23	Additional detail on the types and amounts of debris added and the introduction sequence was added to this response.
RAI 28	Additional information about the Ice Condenser design was included in this response.
RAI 30	This response was updated due to NRC technical staff concerns with the Array and Integrated Prototype Tests. RAIs 14, 15 and 16 cover the new information in detail.

Attachment 2

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC Request for Additional Information

Final Responses

August 13, 2012

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

1. Please state whether or not the break location selection was revisited when the Zone of Influence (ZOI) for fibrous insulation was changed from 17D to 7D. If break selections were not revisited, please provide the rationale for not doing so. If the break selections were revisited, please provide the top four breaks in terms of debris generation for the 7D ZOI (The supplemental response sent by letter dated February 29, 2008, indicates only that the break locations already identified for a 17D ZOI were reassessed for debris quantity generation and confirmed not to have changed relative ranking.)

Catawba Response:

In the time period since the Supplemental/Amended Supplemental Responses were submitted in spring 2008, Catawba has determined that reliance on the WCAP-16710-P jacketed fiber insulation ZOI refinements is no longer necessary, primarily due to large scale fiber insulation replacement in Unit 1 that has already taken place. The Unit 2 fiber insulation quantity is significantly less than that of Unit 1, even after this replacement. Catawba stated this position to the staff in a letter dated July 28, 2009. Additionally, fibrous debris quantities generated from destroyed fiber insulation will be based on the NEI 04-07 GR/SE only (i.e., using a 17D break ZOI).

The replacement of the fiber insulation systems has the same effect from a break location evaluation perspective as any other fiber reduction refinement would. Therefore, the Catawba break locations were revisited in Unit 1 using the post insulation replacement configuration and a 17D ZOI to ensure the limiting break was identified.

Following fiber insulation replacement, each Unit 1 reactor coolant loop still contains limited amounts of fibrous blanket insulation on sections of the hot legs and the crossover legs closest to the steam generators. Fibrous insulation on the steam generators within the 17D ZOI has been replaced with RMI insulation. The amount of blanket insulation remaining on the crossover legs is identical for each of the loops. The 1B loop hot leg has the most fibrous insulation of all the hot legs, followed by the 1D loop, the 1A loop, and finally the 1C loop.

In general, a hot leg break at Catawba generates more debris than a cold leg or crossover leg break. This is due to the fact that the hot legs for the B and C steam generators and the hot legs for the A and C steam generators are adjacent to each other. Thus, a hot leg break on one loop has a larger impact on the adjacent loop than a cold leg or crossover leg break would.

The limiting break from a debris generation perspective is thus on the 1B loop hot leg with a break location adjacent to the steam generator. The next limiting breaks would then be on the D loop hot leg; followed by the A loop hot leg and finally the C loop hot leg. The next limiting series of breaks would be on the crossover legs, in the same order.

In terms of debris generation, breaks in Unit 2 are bounded by the Unit 1 breaks, since Unit 2 contains significantly less fibrous insulation within lower containment.

2. Please state whether the testing identified in the test report WCAP-16710-P, "Jet Impingement Testing to Determine the Zone of Influence of Min-K and Nukon® Insulation for Wolf Creek and Callaway Nuclear Operating Plants," was specific to the Catawba Nuclear Station, Units 1 and 2, (Catawba) insulation systems. If not, please provide information that compares the Catawba encapsulation and jacketing systems structures with the systems that were used in the testing, showing that the testing conservatively or prototypically bounded potential damage to the insulation materials.

Catawba Response:

In the Catawba GL 2004-02 Supplemental Response dated 2/29/2008 and the Catawba GL 2004-02 Amended Supplemental Response dated 4/30/2008, the quantity of fibrous debris generated from destroyed fiber insulation and deposited in the ECCS sump pool was determined using the Zones of Influence (ZOIs) described in both the NEI 04-07 Guidance Report (and the associated NRC Safety Evaluation (GR/SE)) and WCAP-16710-P "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants," Revision 0. Specifically, the Catawba ECCS sump strainers were initially designed using the NEI 04-07 ZOI guidance relating to fiber insulation ZOIs, and the subsequent Integrated Prototype Test (IPT) for chemical effects uses WCAP-refined ZOI values.

In the time period since the Supplemental/Amended Supplemental Responses were submitted, Catawba has determined that reliance on the WCAP-16710-P jacketed fiber insulation ZOI refinements is no longer necessary. Catawba stated this position to the staff in a letter dated July, 28, 2009. Fibrous debris quantities generated from destroyed fiber insulation will be based on the NEI 04-07 GR/SE only, so further discussion of the encapsulation and jacketing systems structures per RAI question 2 is unnecessary. For both jacketed and unjacketed Nukon® fiber insulation types located in the postulated break zones, the ZOI used for quantification of debris is 17D as identified in the GR/SE, Table 3-2.

3. Considering that the Catawba debris generation analysis diverged from the approved guidance in NEI 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology," Revision 0, please provide details on the testing conducted that justified the ZOI reductions for jacketed Nukon®. The information should include the jacket materials used in the testing, geometries and sizes of the targets and jet nozzle, and materials used for jackets installed in the plant. Please provide information that compares the mechanical configuration and sizes of the test targets and jets versus the potential targets and two phase jets in the plant. Please evaluate how any differences in jet/target sizing and jet impingement angle affect the ability of the insulation system to resist damage from jet impingement. Please state whether the testing described in test report WCAP-16710-P was bounding for the Catawba insulation systems. If not, please provide information that compares the Catawba encapsulation and jacketing systems structure with the system that was used in the testing, showing that the testing conservatively or prototypically bounded potential damage to the insulation materials.

Catawba Response:

In the Catawba GL 2004-02 Supplemental Response dated 2/29/2008 and the Catawba GL 2004-02 Amended Supplemental Response dated 4/30/2008, the quantity of fibrous debris generated from destroyed fiber insulation and deposited in the ECCS sump pool was determined using the Zones of Influence (ZOIs) described in both the NEI 04-07 Guidance Report (and the associated NRC Safety Evaluation (GR/SE)) and WCAP-16710-P "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants," Revision 0. Specifically, the Catawba ECCS sump strainers were initially designed using the NEI 04-07 ZOI guidance relating to fiber insulation ZOIs, and the subsequent Integrated Prototype Test (IPT) for chemical effects uses WCAP-refined ZOI values.

In the time period since the Supplemental/Amended Supplemental Responses were submitted, Catawba has determined that reliance on the WCAP-16710-P jacketed fiber insulation ZOI refinements is no longer necessary. Catawba stated this position to the staff in a letter dated July, 28, 2009. Fibrous debris quantities generated from destroyed fiber insulation will be based on the NEI 04-07 GR/SE only, so further discussion of the encapsulation and jacketing systems structures per RAI question 2 is unnecessary. For both jacketed and unjacketed Nukon® fiber insulation types located in the postulated break zones, the ZOI used for quantification of debris is 17D as identified in the GR/SE, Table 3-2.

4. The NRC staff is not convinced that Catawba's currently postulated limiting break, that results in no fine fibrous debris, but does result in 195 ft3 of small pieces and 130 ft3 of large pieces, is truly the limiting break from a final head loss perspective. Please provide the fibrous size distribution (including debris amounts determined) for the debris generation calculation based on the 7D ZOI. Please provide the basis for the determination that no fine fibrous debris would be generated by the limiting break. (The NRC staff considers the assumption of no fine fibrous debris to be non-conservative and inconsistent with previous industry and NRC insulation destruction test data that indicates that a fraction of the debris formed within a 7D ZOI would be destroyed into fines. The NRC staff guidance for break selection (NEI Guidance Report and NRC staff Safety Evaluation) requires that "pipe breaks shall be postulated with the goal of creating the largest quantity of debris and/or the worst case combination of debris types at the sump screen." Fine fiber is a basic constituent of a limiting debris bed. If a different break location would result in the generation of fine fibrous debris, even if the total debris amount is less than the currently postulated Catawba limiting break, that different break may actually be the limiting break. The licensee should evaluate each potential break location from debris generation to transport (including erosion and ensuing transport) to head loss to determine which break is actually limiting.)

Catawba Response:

As discussed in the responses to RAI questions 2 and 3 and in a letter to the NRC staff dated July 28, 2009, Catawba is no longer implementing the jacketed fiber insulation refinements (i.e. the 7D ZOI) identified in WCAP-16710-P. As a result of this change, a 17D ZOI for postulated breaks for both jacketed and unjacketed fibrous insulation will be used in accordance with NEI 04-07 Guidance Report/Safety Evaluation (GR/SE). Consistent with this approach, a more industry standard four size distribution model consisting of individual fines, small pieces, large pieces and intact blankets is being imposed on the debris that is generated. Within the overall 17D ZOI, the size distribution of the debris that is generated varies depending on the distance of the insulation from the break (i.e. insulation debris generated near the break location would consist of more fines and small pieces than insulation debris generated near the edge of the ZOI).

Three sub-zones were determined within the 17 D ZOI for quantifying the debris size distribution. The breakdown of fiber sizes within each sub-zone is provided in Table 4S-1 below:

Table 4S-1

Low Density Fiberglass (LDFG) Debris Distribution Within Each Sub-Zone

Size	7.0 D ZOI	11.9-7.0 D ZOI	17.0 – 11.9 D ZOI
Fines (Individual Fibers)	20%	13%	8%
Small Pieces (<6" on a side)	80%	54%	7%
Large Pieces(>6" on a side)	0%	16%	41%
Intact (covered) Blankets	0%	17%	44%

This change in approach is primarily due to the removal of fibrous insulation from the steam generator barrels and reduced debris transport fractions as a result of approval of the ECCS Water Management License Amendment Request (LAR). The ECCS Water Management LAR and subsequent modifications (implementation of these modifications is complete for both Units as of spring 2011) delays the start time for initiation of containment spray after a high energy pipe break inside containment, allows the system to operate with only one Containment Spray train, increases the minimum required volume of the Refueling Water Storage Tank (RWST), and lowers the RWST lo-lo level. These changes result in higher containment sump pool volumes (due to increased ice melt and increased useable RWST volume) and lower sump pool turbulence (due to lower spray return flows through the refueling cavity drains, and an overall lower flow/approach velocity through the ECCS Sump Strainer).

The Computational Fluid Dynamics (CFD) model previously utilized to calculate debris transport fraction for the various sizes and types of debris was utilized again to quantify the benefits of ECCS Water Management. There were no changes to the model itself, only the input parameters of ice melt flow rate, steady state containment sump pool volume, containment spray return flow rate, and overall flow to the sump recirculation suction piping.

The previous debris quantities reported in the response to RAI question 12 in Catawba GL 2004-02 Amended Supplemental Response dated April 30, 2008, as well as the current debris quantities (modified via fiber reduction, size distribution, and revised CFD model) are provided below in Table 4S-2:

Table 4S-2

Catawba Fiber Insulation Debris Loads – Limiting Break

Nukon® and Thermal-Wrap® Low Density Fiberglass (LDFG)	Debris Quantity		Transport Fraction		Quantity at Sump Strainer	
	Reported on 4/30/2008 (7D ZOI)	Current Debris Quantity (17D ZOI)	Reported 4/30/2008	Water Management Debris Transport Fraction	Reported 4/30/2008	Water Management Quantity at Sump Strainer
Fines	0 ft^3	36.75 ft^3	100%	100%	0 ft^3	36.75 ft^3
Small Pieces	195 ft^3	131.6 ft^3	45%	10.4%	88.3 ft^3	13.69 ft^3
Large Pieces	130 ft^3	42.84 ft^3	10%	10%	13.0 ft^3	4.28 ft^3
Intact Blankets	0 ft^3	45.87 ft^3	0%	0%	0 ft^3	0 ft^3
Total LDFG Generated		257.1 ft^3		Total LDFG Transported		54.72 ft^3

5. Industry debris destruction testing was used as a basis to revise assumptions concerning the ZOIs and debris size distributions for Nukon®, Knauf, and Thermal Wrap low-density fiberglass insulations. Please describe the jacketing, banding and latchinq mechanisms, and cloth covers of these three types of insulation installed at Catawba and compare them to the insulation for which destruction testing was performed in order to demonstrate the applicability of the industry destruction tests results to Catawba.

Catawba Response:

In the Catawba GL 2004-02 Supplemental Response dated 2/29/2008 and the Catawba GL 2004-02 Amended Supplemental Response dated 4/30/2008, the quantity of fibrous debris generated from destroyed fiber insulation and deposited in the ECCS sump pool was determined using the Zones of Influence (ZOIs) described in both the NEI 04-07 Guidance Report (and the associated NRC Safety Evaluation (GR/SE)) and WCAP-16710-P "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants," Revision 0. Specifically, the Catawba ECCS sump strainers were initially designed using the NEI 04-07 ZOI guidance relating to fiber insulation ZOIs, and the subsequent Integrated Prototype Test (IPT) for chemical effects uses WCAP-refined ZOI values.

In the time period since the Supplemental/Amended Supplemental Responses were submitted, Catawba has determined that reliance on the WCAP-16710-P jacketed fiber insulation ZOI refinements is no longer necessary. Catawba stated this position to the staff in a letter dated July, 28, 2009. Fibrous debris quantities generated from destroyed fiber insulation will be based on the NEI 04-07 GR/SE only.

6. Please specify whether latent debris samples were collected as part of the containment walkdowns performed described in the supplemental response sent by letter dated April 30, 2008, and describe how these samples were used to estimate the latent debris quantities for both units. In addition, if samples were not collected, please justify how the use of photographs and walkdown notes of the Catawba containments, as described in the response, provide assurance that the 200 lbm of latent debris assumed for the supporting calculations is bounding.

Catawba Response:

Latent fiber (i.e., lint) quantities and latent particulate (i.e., dust and dirt) quantities at Catawba were estimated using NEI 02-01 containment walkdown guidance, in combination with the NEI 04-07 Guidance Report (GR) and its companion Safety Evaluation (SE). For Catawba, the Unit 2 latent debris estimates were used to represent both containments. Unit 1 is expected to be equivalent to Unit 2 since containment layouts are nearly identical and maintenance and cleaning practices are identical between Units. This assumption was verified via small scale sampling comparisons between Units and the conservatisms applied to the overall totals.

Methodology
The following activities were performed (in accordance with the GR/SE) to quantify the amount of latent debris in containment:

- Estimate horizontal and vertical surface area
- Evaluate resident debris buildup
- Define specific debris densities
- Determine fractional surface area susceptible to debris buildup
- Calculate total quantity and composition of debris

Also in accordance with the GR, containment was segregated into four areas based on the presence of robust barriers and representative surfaces:

- Lower Containment inside the Crane Wall
- Lower Containment Pipe Chase (outside the Crane Wall)
- Upper Containment
- Ice Condenser

Surface types within each of these areas were categorized as (a) Horizontal Floor Surfaces, (b) Horizontal Miscellaneous Surfaces, or (c) Vertical Surfaces. With the sampling surfaces defined, specific areas were chosen in order to obtain their representative online condition.

Sampling media included Masolin cloth and sticky foam. All sampling media was pre-bagged and labeled. Each bag contained a single Masolin cloth and a single sheet of sticky foam (sized approximately 9" × 12"). Each bag was then pre-weighed on a Mettler Toledo PR5002 scale, with a tolerance of ± 0.04 grams.

The area was wiped down with a Masolin cloth to pick up fine debris and to consolidate larger particulate debris. Vertical surfaces were wiped from the bottom up to prevent a loss of debris. The sticky foam sheet was then used to pick up any remaining particulate debris. Both the Masolin cloth and the tacky foam sheet were carefully folded to prevent loss of debris material and placed back in the sample bag. Excess air within the bag was gently forced out to allow the sample to be easily transported and post-weighed. After all sampling was complete the bags were weighed on the same scale. The difference between the pre- and post-weights were then used to calculate the mass of the debris collected.

Sample mass measurements were increased by an offset to account for a number of possible sampling and measurement errors including loss of sample media to the sample surface, air movement above the scale during measurement, and the tolerance of the scale. The error due to air movement and the tolerance of the scale could also act in a conservative direction for some samples (i.e., increase the measured sample mass), therefore the offset applied to these samples further increases the conservatism leading to a higher estimated latent debris loading.

There were 59 individual latent debris samples taken, with the following itemization by surface type:

Horizontal Floor Surfaces: 18 samples

Horizontal Miscellaneous Surfaces: 25 samples

Vertical Surfaces: 16 samples

Once the sample debris mass for each surface type was quantified via scale measurements, the specific debris density for each sampled area was computed by dividing the individual sample masses by their respective sampled surface areas. The sample densities were then grouped into the following sample sets based on common surface type and location, common associated work activities in each area, and cleanup procedures (e.g., similar work activities and cleanup would be expected for the floors in Lower Containment inside the Crane Wall and in the Pipe Chase):

- Horizontal floor surfaces in Lower Containment inside the Crane Wall and in the Pipe Chase
- Horizontal miscellaneous surfaces in Lower Containment inside the Crane Wall and in the Pipe Chase
- Vertical surfaces in Lower Containment inside the Crane Wall and in the Pipe Chase
- Horizontal floor surfaces in Upper Containment and inside the Ice Condenser

- Horizontal miscellaneous surfaces in Upper Containment and inside the Ice Condenser

  Note: The mean density for the horizontal miscellaneous surfaces measured through the above process was less than all other areas of containment. Instead of using the measured value, a mean density of twice that of lower containment horizontal miscellaneous surfaces (maximum debris density) was used in the calculation to more conservatively account for all area of upper containment.

- Vertical surfaces in Upper Containment and inside the Ice Condenser

A statistical analysis was then performed using the grouped sample densities to provide a conservative assessment of debris buildup over a given surface type. While the GR/SE states that the average of at least three samples for each surface type should be applied to the entire surface, the Catawba analysis goes a step further by determining the 95% confidence interval of the mean (average) debris density. This approach provides margin in the calculation of total latent debris inside the containments. The maximum predicted mean latent debris densities were then multiplied by the appropriate actual surface areas inside the Catawba containment, which were based on reference drawings and information developed from the walkdowns. The total latent debris loads calculated conservatively assume that 100% of the estimated surface areas in containment are susceptible to debris accumulation.

Using this methodology, the extrapolated latent debris mass total for the Catawba Unit 2 containment was determined to be approximately 113 lb, which bounds Unit 1 as reported in the Catawba GL 2004-02 Supplemental Response dated 2/29/08, Enclosure 2, item 3(d)2. It should be noted that applying the methodology described in the SE of using a simple sample mean, the total estimated mass would be approximately 70 lbm.

For conservatism, an overall value of 200 lb was assumed for the total latent debris quantity in each of the Catawba Unit 1 and Unit 2 containments, 30 lb (15%) of which is considered to be latent fibers per the GR/SE.

7. Please describe the analytical method used to extrapolate the total amount of latent debris in containment. If a statistical method was used, please provide the confidence level of the results.

Catawba Response:

Please reference the response to RAI question 6 of this submittal for the details regarding the methodology used to calculate the amount of latent debris within containment at Catawba.

8. Please provide the details of the methodology used for the tag and label refinement evaluation. Please provide details of the equipment qualifications and engineering judgments used as basis for reduction of tag and label quantities assumed to fail and reach the sump.

Catawba Response:

Please reference the response to RAI question 10 of this submittal for the details regarding the Catawba tag and label refinement evaluation.

9. Please provide the technical basis for the assumption of 10-percent erosion of 'fibrous debris in the containment pool. If testing was performed to support this assumption, please demonstrate the similarity of the flow conditions, chemical conditions, and fiberglass material present in the test versus the conditions expected in the Catawba containment pool.

<u>Catawba Response:</u>

The quantity of constituent fiber fines transporting to the Catawba strainer due to the erosion of submerged but non-transported pieces of fiber insulation was determined by testing in order to refine the conservative erosion assumptions documented in the NEI 04-07 GR/SE.

The objective of the erosion testing was to quantify any containment pool flow-induced erosion/deterioration that may occur on low-density fiberglass insulation (LDFG). This was accomplished by subjecting a measured test sample of the LDFG material type to a room-temperature solid water flow in a closed vertical test loop (VTL) apparatus and a horizontal test flume (TF) for durations of up to 72 hours, and quantifying any mass that may have eroded off of or otherwise dislodged from the test sample. These two apparatuses (VTL and TF) were used to compare the different turbulence and energy effects upon the insulation, as well as observing the effects of the orientation of the sample with respect to the water flow. To quantify the fibrous mass loss, the dry weight of the test samples before and after the test was measured and recorded. The testing was conducted on both large and small pieces of LDFG to observe any effects that size or surface area had on the sample's erosion.

Subsequently, a 30-day erosion test in the horizontal flume apparatus was also conducted. Analysis of this test data provided further insight into the nature of the LDFG sample composition and consequently, its erosion characteristics. Primarily, it was observed that during 30 days of flow impingement, the sample did not continuously disintegrate. The fiber insulation samples appeared to yield loosely bound fiber fines early in the test, after which the erosion effects subsided.

<u>Test Inputs</u>
Erosion tests were conducted with LDFG insulation samples in conditions intended to mimic, or be conservative with respect to, the expected post-LOCA plant conditions.

Debris Type and Size:
Both Nukon® and Thermal-Wrap® fiber insulation exist in the break zones of influence in the Catawba containments, and for the purposes of LDFG evaluation can be considered equivalent consistent with the LDFG destruction pressures discussed in the NEI 04-07 GR/SE, Section II.3.1.1. The erosion testing used Nukon® samples with the same bulk density (2.4 lb/ft^3) as that used in the plant. The Nukon® fiber insulation sheets were cut into 6"×3"×1" rectangles to represent the large pieces, and into 1"×1"×1" squares to represent the small pieces (an extra large piece measuring 6"×6"×1" was also included). Samples were then boiled in tap water for ten minutes to remove the binder, in order to simulate the conditions the fiber insulation would

undergo during the blowdown and ECCS sump pool recirculation phases of the predicted post-LOCA response.

Test Environment:
The insulation samples were subjected to a flow erosion environment in both a vertical test loop apparatus and a horizontal flume. Each test consisted of subjecting insulation samples to flow erosion by filling the VTL or TF with tap water and then circulating the water to bound the flow conditions that occur in the ECCS sump pool. The samples were always completely submerged during testing to ensure conservative erosion. The large Nukon® samples were fastened to a screen to impede unnecessary movement. The small Nukon® samples were stabilized by placing them in a wire cage in the flow stream, such that there was no interference with either flow or the release of eroded material.

Flow Velocity:
The erosion tests were performed at a flow velocity that is equal to the incipient tumbling velocity for the specific size. For the LDFG samples tested, the flow velocities were determined to be 0.37 feet per second for the large pieces and 0.12 feet per second for the small pieces. Since the incipient tumbling velocity is the velocity at which the debris would start moving, this velocity bounds the greatest velocity that a piece of insulation lying in the containment pool would experience without being transported to the ECCS sump strainer. Therefore, it is considered the velocity that would produce the most fiber fines from submerged, but not transported, fiber insulation pieces.

Water Temperature and Chemistry:

- Temperature – As discussed previously, the LDFG samples were boiled prior to being subjected to flow impingement testing, to simulate the conditions present during blowdown and recirculation. The actual tests were conducted in the VTL and the TF in room-temperature tap water (i.e., approximately 60°F-80°F). The temperature of the water increased during testing due to continuous pump heating (up to 110°F for longer-duration tests). It was determined that viscosity effects on the erosion rates were insignificant.
- Chemistry – The erosion tests were conducted in tap water and not the buffered or borated water predicted to be present in the containment sump pool post-LOCA. The use of tap water is considered appropriate because the lack of chemicals such as soluble aluminum, boron, or pH buffers will not affect the amount of fibers that would erode from a Nukon® LDFG insulation sample.

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

Analysis of Erosion Test Data

During the erosion tests, the small Nukon® samples generally eroded more than the large samples, despite the large samples undergoing a higher flow velocity. Small samples eroded more fibrous mass due to their increased surface area exposed to the water flow and their being prepared for the tests by shredding, which produced more fines available for transport. Since the small samples eroded more than the large samples, the test data analysis utilized only the small sample results in order to generate conservative fiber erosion quantities (therefore these higher small piece erosion rates are applied to both size ranges of submerged, non-transported fiber insulation).

The small fiber test samples lost, on average, about 3% to 7% of initial weight for any given test duration, with the raw data range spanning 0% to 20%. Because the LDFG erosion data was not consistent, the data was analyzed and results compared using several different approaches:

1. Assume the 30-day small sample erosion test results represented the most accurate erosion rate.
2. Determine the weight loss per hour rate for all small sample erosion tests, and then extrapolate that weight loss per hour value to 30 days to properly account for the ECCS mission time.
3. Average all of the small sample erosion values regardless of test duration (including root mean square (RMS) error), and assume this value applies for the ECCS mission time.

Application of approaches 1 and 2 above yielded 30-day fiber erosion estimates that appeared to be non-conservative when compared to the majority of the small sample data points.

Since the fiber erosion test results showed wide scatter across all test durations, the assumption was made that fiber erosion is not directly time-dependent, and therefore could be conservatively described by averaging all of the small sample erosion test results to reach an overall erosion value (i.e., approach 3 above). Additionally, as noted previously it was observed that during the 30-day erosion test the samples did not continuously disintegrate. The fiber insulation samples appeared to yield (transport) loosely bound fiber fines early in the test, after which the erosion effects subsided. As such, the overall erosion value calculated from the small sample average is considered applicable to a 30-day mission time.

The calculated average of the small sample fibrous erosion test results was approximately 6% of initial weight, with an error of ±4% as determined by RMS error analysis versus the calculated average. Approach 3, then, determined a conservative estimate of the overall fiber erosion value to be 10% of the initial fiber weight (6% + 4%).

Therefore, the attrition/erosion mechanism that strips away the loose pieces of LDFG via water impingement is conservatively estimated to reduce an initial weight of submerged, non-transported fiber insulation by 10% over the 30-day ECCS mission time.

Subsequent to the preceding series of vendor erosion tests, extensive discussions were held between NRC technical staff, the vendor, and Licensees (including the Duke Energy plants) regarding the testing configuration and analysis methodology. This led NRC to request a confirmatory LDFG erosion test from the vendor to address issues identified with the test flume and erosion sample configuration. The 30-day confirmatory erosion test series was completed by the vendor in 2010 and confirmed a 30-day erosion value of 10% for both large and small piece LDFG.

10. Please provide details of the tags and labels equipment qualifications and engineering judgments used as the basis for reduction of tags and label quantities which are assumed to fail and reach the sump. Specifically, please justify the application of Institute of Electrical and Electronics Engineers (IEEE) Standard 323-1974, "IEEE Standard for Qualifying Class 1 E Equipment for Nuclear Power Generating Stations," in qualifying Electromark® labels for a post-loss-of-coolant-accident (post-LOCA) environment with respect to nondebris transport to the sump strainer.

Catawba Response:

The assumptions and engineering judgments used in the Catawba tag and label reduction evaluation performed subsequent to the initial assessment were provided in the responses to items 3(d)1, 3(d)2 and 3(i)5 of Enclosure 2 of the Catawba GL 2004-02 Supplemental Response dated 2/29/08.

The tag and label assessment subsequently included only one refinement in the form of a qualified tag reduction. For this reduction, it was assumed that metal tags hung with braided stainless steel connections would either not fail, or would sink and not transport. These robust metal tags are not the same as qualified Electromark® labels, which are discussed later in this response.

The transported tag and label quantifications by area of Containment were reported in Table 3D3-2 of Enclosure 2 of the Catawba GL 2004-02 Supplemental Response dated 2/29/08. The information in this table is recreated below in Table 10S-1 for convenience.

Table 10S-1

Catawba Refined Miscellaneous Latent Debris Quantities

Type of Debris	Lower Containment (Inside Crane Wall)	Lower Containment (Outside Crane Wall)	Upper Containment	Ice Condenser	Total
Stickers & Labels (ft^2)	116.611	58.669	21.380	2.850	199.51
Plastic Tags w/Adhesive (ft^2)	1.469	2.774	4.099	4.600	12.942
Plastic Hanging Tags (ft^2)	3.438	5.000	4.450	1.500	14.388
RMI ID Stickers (ft^2)	277.597	66.234	0.000	0.000	343.831
Ice Condenser Debris (ft^2)	N/A	N/A	N/A	15.3	15.3
Total (ft^2)	399.115	132.677	29.929	24.250	585.971

For the purposes of this response, "labels" refers to any thin pliable sticker or marker that is affixed with adhesive. The term "tag" refers to any relatively thick rigid plastic tag or placard that is hung or affixed with adhesive.

As stated in item 3(i)5, Electromark® labels located outside the Crane Wall in the lower containment at Catawba have been evaluated as capable of withstanding the limiting break, and thus were removed from the initial quantification of tag and label debris assumed to transport to the ECCS Sump Strainer. Electromark® labels located inside the Crane Wall in lower containment are assumed to fail.

As stated in item 3(d)2, it is not possible to conservatively estimate the percentage of tag and label surface area that is in the ZOI; therefore, all tags and labels inside the crane wall in lower containment will be assumed to fail.

Lower Containment
In an Ice Condenser containment, the areas of the lower containment outside the Crane Wall and <u>not</u> inside the Ice Condenser Lower Plenum or the Pipe Chase are located between the Ice Condenser end walls (approx. 60 degrees of circumference) and in the rooms above the Pipe Chase. Plastic tags in this vicinity are generally outside the break ZOIs and are assumed to deform, but not become overly pliable (i.e., they will not deform enough to pass through an obstruction that has a smaller dimension than the tag).

Ice Condenser Reduction
Tags and labels located within the Lower Plenum of the Ice Condenser (and outside the Crane Wall) are assumed to fail since the break energy is directed into this plenum by design.

Tags and labels located within the Upper Plenum of the Ice Condenser would not be expected to fail immediately during the initial venting of air and steam; however, exposure to the post-LOCA environment and containment spray may lead to eventual detachment even though steam flow is negligible. A minor portion of the tags and labels located in the Upper Plenum of the ice condenser are not located above the ice basket array and are located above horizontal surfaces. As these tags and labels fail, they will fall straight down and are not expected to transport further due to containment spray.

It is likely that many of the remaining tags and labels that fail within the Upper Plenum of the ice condenser will fall directly into the ice baskets themselves. Given the ice baskets are made of perforated sheet metal with 1" by 1" holes and the bottom of the baskets are covered by a grid and wire mesh, any tags and labels that fall into the ice baskets will not be able to exit. It is conservatively assumed that ice basket openings comprise 50% of the ice basket array cross-sectional area. Tags and labels that do not fall into the ice baskets themselves could fall into the space between the baskets and the lattice frame which provide support for the baskets. While the lattice frame does create a tortuous path for the tags and labels, it is not possible to conservatively estimate an appropriate quantity of labels that would remain within the lattice structure; therefore, no reduction was taken for tags and labels that may fall into this area.

Elevation 565'+3" Reduction
The rooms above the pipe chase at elevation 565'+3" are not subject to jet impingement or containment spray. Initially, the rooms will not be flooded, but as the accident progresses the floor elevation of these rooms may be reached. Access to the rooms is gained through an opening in the floor from the pipe chase below. Once the rooms are flooded, velocities in the rooms are expected to be very low and tags and labels would not transport to the pipe chase below. Only tags and labels directly above the floor opening are assumed to transport to the pipe chase below.

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

Upper Containment Reductions
The majority of tags and labels within Upper Containment are located between the ends of the ice condenser walls, in the fan pit, and around the personnel hatch. Tags and labels that detach are expected to fall straight down and there are none that would be expected to fall directly into the refueling canal.

It is conservatively assumed that all tags and labels that reach the fan pit will pass to the refueling canal. A majority of tags and labels outside the fan pit are located directly above grated platforms. It is judged that a majority of these labels will be easily captured by the grating and thus the quantity of labels above grating is reduced by 75%. Although highly unlikely, it is conservatively assumed that all tags and labels that detach and fall to the concrete operating floor will be transported over the 3 inch curbing around the refueling canal and through the elevated refueling canal drains to lower containment.

Qualification of Electromark® labels
The Electromark® labels located in containment were qualified for the LOCA environment via a comprehensive test program. The purpose of this program was to demonstrate the suitability of application for pressure sensitive markers in being able to remain in position (on equipment or structures) throughout a specified lifetime, including background radiation followed by a simulated LOCA. The safety function demonstrated was that the markers would remain affixed to the equipment or structure without falling off.

This test program was conducted under the general guidelines as suggested in IEEE 323-1974 "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations". The various phases of the program are outlined following:

1) Heat Aging – Simulation of long-term exposure to plant ambient conditions at typical ambient temperatures and atmospheric pressure for a period of several years. On the basis of the suggestions and procedures contained in IEEE 117 and IEEE 275, the 10°C rule was utilized to extrapolate an aging temperature to demonstrate a qualified life period by accelerated aging at elevated temperatures.
2) Radiation Aging – At the conclusion of the thermal aging period the samples were inspected for degradation and loss of function, and then exposed to a cobalt-60 source of gamma radiation at a nominal dose rate of 0.5 Mrads (megarads) per hour until a total accumulated dose of 200 Mrads had been received. The samples were then inspected again for wear and degradation.
3) LOCA simulation – The samples were installed inside a pressure vessel and subjected to an environmental exposure of steam and chemical spray for a period of 30 days in accordance with the suggested IEEE 323-1974 profile. At the conclusion of the exposure the samples were again inspected and compared with the control samples for suitability of function.

11. Please provide the results of the array testing conducted at Alion Science and Technology Corporation and the Integrated Prototype Test (IPT) testing conducted at Wyle Laboratories. For the IPT testing, in addition to head loss values, please provide the results as a function of time. Please provide a thorough description of the methodology used to combine the two test results to determine the final head loss for the strainer debris bed. If a correlation was developed to determine head loss, please provide the correlation along with the assumptions and bases used in the development of the correlation.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information below pertains to the Chemical Precipitates Head Loss test series performed in January/February 2011, from which the bounding run is documented as the test of record for the Catawba ECCS Sump Strainers.

Due to the redesign of the strainer tests between 2007 and 2011 as described in the preface of this submittal, the RAI question from the staff as written above in response to the 2008 Catawba Generic Letter 2004-02 Supplemental Response dated 2/29/08 (as amended by submittal dated 4/30/08) no longer applies in the same manner as it was originally intended. The primary difference is that the strainer head loss result is no longer determined by combining two separate test outcomes; the Chemical Precipitates Head Loss test series was comprehensively designed (with technical staff input) to generate one distinct result to simplify the certification process. To provide fidelity, the series consisted of two similarly-conducted Catawba strainer tests, with the bounding result documented as the test of record. Since this RAI question is clearly focused on identifying the strainer head loss as a function of the ECCS mission time (and information regarding the methodology used to determine it), that will be the approach used to respond to Catawba RAI question 11. This general approach to all of the testing-related RAI questions was discussed and agreed to with the technical staff on the September 1, 2009 public telecon between Duke and NRC.

The ECCS Sump Strainer total head loss following a postulated LBLOCA is shown as a function of ECCS sump pool temperature and approximate ECCS mission time in Table 11S-1 following, for the bounding Catawba unit.

Table 11S-1

Catawba ECCS Sump Strainer Predicted Post-LOCA Head Loss

ECCS Sump Pool Temperature (°F)	ECCS Mission Time (approx.)	Total ECCS Sump Strainer Head Loss (ft-water)
199	0 min	6.30
190	8 min	6.38
180	22 min	6.47
170	50 min	6.58
160	1.2 days	9.99
140	3.5 days	10.50
120	16 days	11.15
100	>25 days	12.03
90	>25 days	12.70

Table Notes:

- Values are for the limiting Catawba ECCS Sump Strainer in Unit 2
- Assumes Maximum Safeguards (three-train ECCS flowrate)
- "ECCS Mission Time" begins at swapover to sump recirculation phase

The total ECCS Sump Strainer head loss in the above table is the head loss associated with the clean strainer combined with the predicted debris head loss (conventional and chemical precipitates) as extrapolated from data determined by empirical test.

Methodology

The methodology used to determine the ECCS Sump Strainer head loss at extended sump pool temperatures is based on the results of the Chemical Precipitates Head Loss test series, a series run at steady state temperature for a limited amount of time. As such, translation of the test results to post-accident plant conditions requires the post-processing of specific parameters (i.e., flow rate and pool temperature) in order to conservatively calculate the predicted head loss.

The calculation methodology also assumes that chemical effects (in the Catawba post-accident sump pools, the precipitate is sodium aluminum silicate) on the strainer head loss occur only after the pool temperature cools to approximately 165°F. At pool temperatures above this threshold temperature, the peak conventional debris head loss is applicable. The effect of chemical precipitates on the strainer head loss can be seen in Table 11S-1 at pool temperatures below 170°F. This threshold temperature for precipitates was determined using staff guidance and conservatively predicted aluminum concentrations in the pools; the inclusion of the delayed precipitation approach and the associated temperature threshold in the strainer certification was discussed in a telecon between Duke and NRC staff on March 19, 2012.

The raw strainer head loss results from the Chemical Precipitates Head Loss Test series were post-processed by performing an appropriate and bounding curve fit to the data obtained after all debris had been added and the head loss had stabilized. This generated an expression for the test strainer head loss as a logarithmic function of time, per NRC guidance. After this, the pressure differential and flow data were conservatively corrected to accommodate test instrument uncertainty, and the test head loss trend extended to 30 days. The bounding, corrected test head loss value was then transposed to various sump pool temperatures of interest.

Nine target temperatures (as identified in Table 11S-1) were chosen as representative of the ECCS mission time, and the test condition head loss transposed to each target pool temperature to obtain a predicted post-LOCA ECCS Sump Strainer head loss at that point. The general correlation used to perform this transposition is:

$$\frac{h_{L,2}}{h_{L,1}} = L_{Frac}\frac{\mu_2}{\mu_1}\frac{Q_2}{Q_1} + T_{Frac}\frac{\rho_2}{\rho_1}\left(\frac{Q_2}{Q_1}\right)^2$$

Where:

Q_1 = Test tank flow rate

Q_2 = Target flow rate for the actual plant condition

μ_1 and ρ_1 = Dynamic viscosity and density of water at test tank temperature

μ_2 and ρ_2 = Dynamic viscosity and density of water at target pool temperature

$h_{L,1}$ = Flow head loss from bounding test curve

$h_{L,2}$ = Flow head loss at target flow rate, Q_2 and target pool temperature

T_{Frac} = Turbulent fraction of the flow

L_{Frac} = Laminar fraction of the flow

The laminar and turbulent fractions of the flow were determined using flow sweep data, obtained at the end of each run during the Chemical Precipitates Head Loss Test series.

12. Please provide information that establishes that vortex testing was conducted at less than or equal to the expected 3.75-inch minimum strainer submergence. The licensee's response to RAI question 38 in Enclosure 1 to the supplemental response sent by letter dated February 28, 2008, and Enclosure 2 of this supplemental response, Section 3(f)(2), state that the strainer modules are submerged by 3.75 inches under limiting sump level conditions. The licensee's response to RAI question 38 states that testing was conducted at a submergence of 3 inches.

    Enclosure 2, Section 3(f)(3), states that the testing was conducted with a "few inches" of water coverage above the strainer modules. Separately, Enclosure 2, Section 3(f)(3), states that approach velocities for testing were between 0.01 ft/sec and 0.09 ft/sec, while the expected maximum approach velocity for the plant strainer is 0.045 ft/sec. In order to clarify the conditions under which vortex testing was conducted, please provide the following information:

    a. Please provide the basis for the maximum approach velocity value of 0.045 ft/sec.
    b. Please discuss how flume velocity was controlled during vortex testing.
    c. Please provide a quantitative value for the approach velocity during which any vortices were observed to form.
    d. Please provide a quantitative value for the vortex suppressor grating submergence.
    e. Please verify that all vortex testing was conducted at less than or equal to 3.75 inches of strainer submergence, with or without a vortex suppressor grating.
    f. Please state whether vortex formation occurred during testing and what conditions were present at such times (submergence level, approach velocity and grating installation).

Catawba Response:

a. For vortex testing purposes, the as-built maximum approach velocity for the top hats closest to the ECCS suction lines (assuming operation with 2 RHR pumps and 2 Containment Spray pumps) was determined to be 0.048 feet per second in Catawba Unit 2, which bounds Unit 1. This approach velocity does not use the normalized flow distribution approach. Instead, the flow is distributed among the top hat modules such that the internal losses within the strainer top hat assemblies and plenums are pressure balanced. This results in a non-uniform flow distribution, which is used to determine the approach velocities. With an initially clean ECCS sump strainer surface, approach velocities for the top hat modules closest to the pump suction lines are expected to be higher than the predicted Catawba nominal approach velocity (i.e. about 0.021 feet per second) by approximately a factor of two.

   It should be noted that CNS submitted a License Amendment Request for the ECCS Water Management Initiative, which was approved by the NRC. In relation to ECCS recirculation flow, this license amendment allows the Containment Spray system to operate with only one pump. This will decrease the overall recirculation flow (and thus approach velocity) through the ECCS strainer by approximately 25%. Implementation of the ECCS Water Management Initiative modifications is complete for both Unit 1 and Unit 2.

b. During vortex testing, flume velocity was controlled via a throttle valve on the downstream side of the recirculation pump. Vortex testing was performed by initially establishing flow at 0.01 feet per second for a time of 10 minutes, without a vortex suppressor installed. Flow was then increased by 0.01 foot per second increments until a vortex was observed. A minimum of 10 minutes was allowed at each flow rate to allow time for a vortex to form. Once an air-entraining vortex was observed, the suppressor was installed. Flow was incrementally increased in 0.01 foot per second increments up to a maximum test approach velocity of 0.09 feet per second, which is approximately twice the maximum expected approach velocity (0.051 ft/sec) for the Catawba Units.

c. Without vortex suppression installed, at approach velocities at and above 0.04 feet per second an air-entraining vortex was present. With the vortex suppressor installed, vortices were eliminated and only minor surface dimpling remained up to the maximum test approach velocity of 0.09 feet per second (approximately twice the current maximum expected Catawba approach velocity).

d. The in-plant configuration has the top of the vortex suppressor grating at an elevation of 554 feet, 9 inches, which is also the same as the minimum flood level in containment. It should be noted that this minimum flood level is based on a number of significant conservatisms. It is calculated based on the break being small enough that no ice melt occurs, the Reactor Coolant system remaining water solid, the Refueling Water Storage Tank being at the minimum volume allowed by plant Technical Specifications, and the incore room beneath the reactor is completely flooded. In addition, with a break resulting in these conditions, the ECCS flow is significantly less than the full ECCS flow modeled in vortex testing.

   With implementation of the ECCS Water Management Initiative modifications, the minimum Technical Specification volume for the Refueling Water Storage Tank was increased and the lo-lo Refueling Water Storage Tank level (where pumps are transferred to the recirculation mode of ECCS operation) was reduced. Both of these changes in RWST setpoints directly contribute to increased ECCS sump pool volumes.

e. During vortex testing, the water level was maintained at approximately three inches above the Top Hat straining surface.

   Refer to Figures 12S-1 and 12S-2 below for clarification of vortex grating submersion during testing and the as-built plant configuration.

   Note: The clearance dimensions provided in the CNS GL 04-02 Supplemental Response dated 2/29/08 were based on the as designed configuration and were based on the minimum clearance allowed between the top of the flow plenum and the bottom of the vortex suppression grating. The dimensions provided below refer to the as-built configuration.

f. Vortex testing was performed with a submergence level consistent with Figure 12S-1. Vortices were observed at flows of 0.04 feet per second and above without the vortex suppressor installed. With the vortex suppressor installed, no vortices were observed up to flows of 0.09 feet per second (approximately 2 times the maximum approach velocity of 0.051 ft/sec).

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

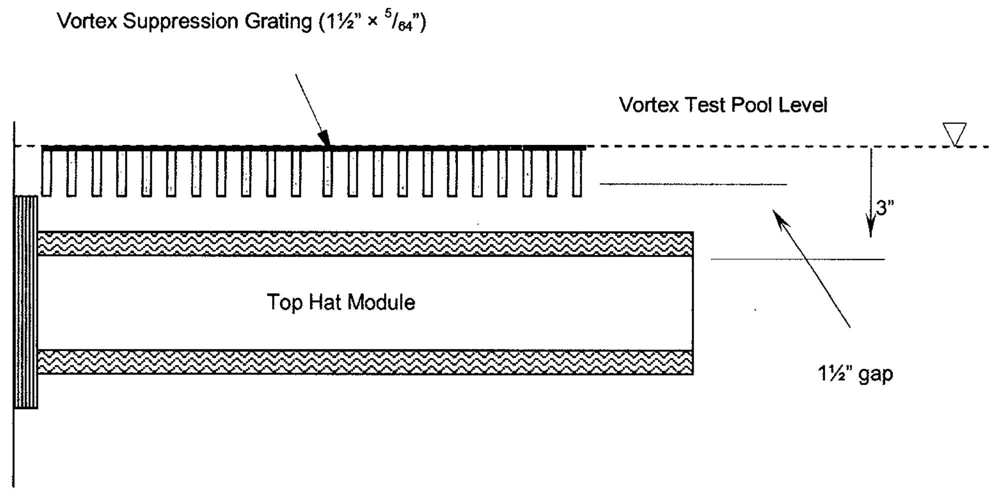

Figure 12S-1: Top Hat Strainer Module Submergence Vortex Test Condition

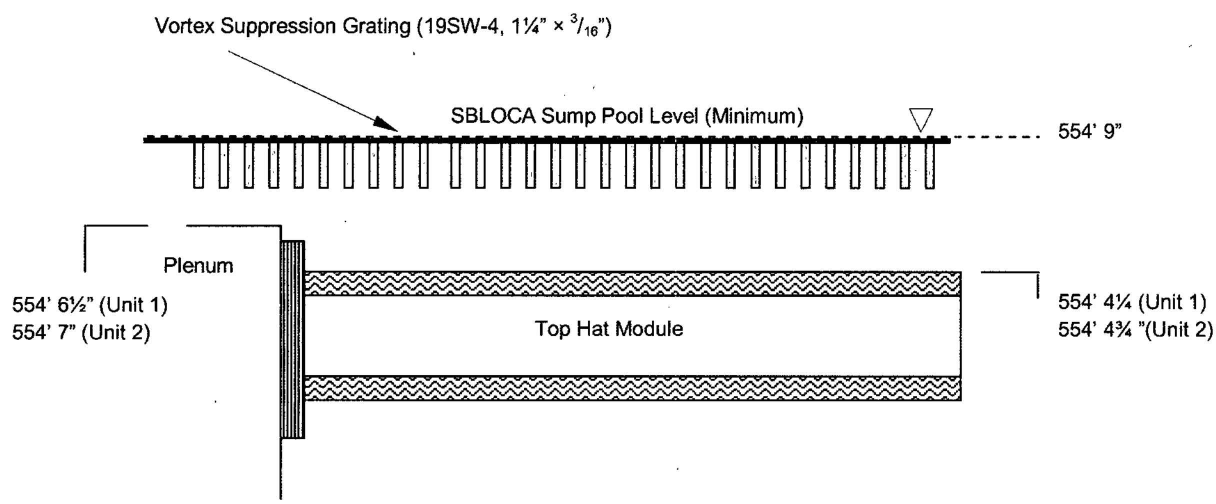

Figure 12S-2: Top Hat Strainer Module Submergence Plant Conditions

13. Please provide a response to the question from the NRC Content Guide sent by letter dated November 21, 2007, relating to Enclosure 2 of the supplemental response sent by letter dated February 29, 2008, Section 3(f)(5), regarding the ability of the strainer to accommodate the maximum potential debris volume. This response should apply specifically to the Catawba strainer and not be a generic answer.

Catawba Response:

As stated in Catawba GL 2004-02 Supplemental Response dated 4/30/2008, Catawba predicted 101.3 ft^3 of Low Density Fiberglass (LDFG) Insulation to be transported to the ECCS sump strainer. Subsequent to that that submittal, Catawba has removed significant amounts of fibrous insulation from containment, discontinued reliance on WCAP-16710-P "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants", and re-performed Computational Fluid Dynamics analyses for the approved ECCS Water Management Initiative modifications. These changes result in a bounding transported LDFG insulation volume of approximately 55 ft^3 (reference response to RAI question 4 of this submittal for details regarding LDFG transported to the strainer).

The non-LDFG debris quantities expected to transport to the strainer (and their characteristics) were provided in the Catawba GL 2004-02 Supplemental Response dated 2/29/2008, Enclosure 2, items 3(c)2, 3(d)3, and 3(h)6. Subsequent to that submittal, Catawba adjusted the unqualified epoxy coatings failure rate and thus the particulate debris quantity for conventional debris head loss testing, using the same methodology as McGuire which was described in the McGuire GL 2004-02 Supplemental Response dated 2/28/08, Enclosure 2, item 3(h)(5), and is further described/justified in response to RAI question 26 from NRC Letter dated 11/18/2008. The appropriate values are provided in Table 13S-1 below for convenience, along with the equivalent volume conversions for each debris type.

Table 13S-1

Non-LDFG Debris Quantities Transported to Catawba ECCS Sump Strainer*

Debris Type	Debris Type Density	Debris Quantity at Strainer	Equivalent Debris Volume at Strainer
Qualified Epoxy Coatings (5D ZOI)	118 lb/ft^3	155.8 lb	1.32 ft^3
Unqualified Epoxy Coatings	94 lb/ft^3	216.7 lb	2.31 ft^3
Unqualified Alkyd Coatings	98 lb/ft^3	10.8 lb	0.11 ft^3
Latent Dirt/Dust	169 lb/ft^3	170 lb	1.01 ft^3
Latent Fiber (lint)	2.4 lb/ft^3	30 lb	12.5 ft^3
Miscellaneous Latent Debris** (tags, labels, etc.)	NA	586.0 ft^2	NA

* Note: Destroyed stainless steel RMI is assumed to not transport to the ECCS Sump Strainer.

** Note: Miscellaneous latent debris is assumed to reduce the strainer flow area for maximizing the approach velocity, but has an insignificant interstitial volume contribution due to the debris being characteristically thin.

Thus, the total volume of debris (LDFG and other) expected to be transported to the ECCS sump strainer after a limiting break is approximately is 72.25 ft^3 (the sum of the debris volumes in the above table and the bounding transported LDFG insulation volume total). The total interstitial volume of the limiting (Unit 2) Catawba Strainer is 513 ft^3.

During accident conditions, the debris bed will initially accumulate non-uniformly on the strainer. The approach velocity will vary across the individual strainer top hats and across the array based on the location of the top hats relative to the recirculation suction piping. Locally, the debris bed will build axially from the top hat base plate out to the free end, up to the maximum debris load. However, since the total transported debris volume (as demonstrated above) is not sufficient to completely fill the strainer interstitial volume, the strainer surface will retain its complex shape (multiple top hat cylinders with flow paths outside and inside the cylinder) and flow area. With no decrease in top hat module flow area, the evaluated approach velocities remain bounding.

14. Please provide information that verifies that the debris preparation and introduction methods used during the array test and IPT were prototypical or conservative with respect to the transport evaluation for the plant. In general, protocols for fibrous debris preparation result in debris that is coarser than predicted by the plant-specific transport calculation. In addition, the NRC staff has noted that debris introduction frequently results in agglomeration of debris such that it may not transport to the strainer prototypically or create a prototypical debris bed. Both of these issues can result in non-conservative head loss values during testing.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information below pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Strainers.

NRC staff guidance from March of 2008 as well as input from discussions with the staff were used for test protocol development. Nukon® fiber utilized for the Chemical Precipitates Head Loss test series was purchased in a heat treated pre-shredded condition. The fiber was then boiled for a minimum of 20 minutes and divided evenly into the required number of 5 gallon buckets such that each bucket contained approximately 0.25 lbm fiber. The buckets were then agitated with a paddle style power mixer to separate the fiberglass into individual strands (fines). The fiber/water mixture was then sampled in a clear pan and inspected over a light source to ensure the mixture was as close to 100% fines as practical. If large or small pieces remained, the mixture was agitated and sampled again until it was deemed acceptable.

After all of the particulate surrogates had been introduced to the test tank, the fiber mixture was then slowly introduced into the test tank on the opposite side of the strainer test array. The main volume of the test tank was equipped with three agitators that were controlled via variable frequency drives in order to keep the tank well mixed and to keep debris from settling.

Prior to testing, a hydraulic shakedown of the test system was performed to ensure acceptable performance. This shakedown was performed without paint surrogate or other particulate debris in the tank, so that the fiber transport and potential agglomeration could be observed. During this shakedown, the direction and speed of the agitators were adjusted as well as the height of water in the test tank. The fiber transport and agglomeration issues identified by the technical staff during prior testing were eliminated by tuning the system in this manner.

The debris preparation, introduction, and transport protocol for the Chemical Precipitates Head Loss test series was identical to the protocol used in the 2009 Confirmatory Head Loss test series identified in the Preface of this submittal. Photos and videos of debris preparation, introduction and transport from the 2009 testing series were provided to the staff in July 2009. The staff concluded that the methods and protocol being utilized for conventional debris preparation and introduction during the tests met NRC expectations.

15. Please provide information on the flow fields in the array test. The NRC staff is concerned that non-prototypical debris distribution may have occurred during testing as a result of stirring of the tank. Stirring can result in the transport of debris that would otherwise not transport, or result in debris being washed from the strainer screen surfaces. Either of these phenomena can result in reduced (non-conservative) head loss values during testing.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information below pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Strainers.

The test tank used for the Chemical Precipitates Head Loss testing was a custom made tank measuring 4.25 feet x 20 feet. The water depth was controlled at approximately 54 inches. The 6 top hat assemblies, consisting of two 24 inch, two 36 inch and two 45 inch long top hats arranged in a 2 × 3 array, were located at one end of the test tank, opposite the loop return piping end. The spacing of the top hat assemblies (both from the tank bottom and within the array) was similar to the spacing in the installed plant strainer. In addition, baffles were built within the strainer portion of the tank to minimize the area that debris could settle and maximize the debris attracted to the top hat straining surface.

The main test tank volume was equipped with 3 agitators which were driven via variable frequency drive devices that were capable of changing the speed and direction of the agitators. These agitators ensured the water in the test tank remained sufficiently turbulent to prevent particulate and fibrous debris from settling in the main tank volume during the execution of the testing.

A 30 inch vertical divider plate separated the strainer portion of the tank from the main volume and shielded the top hats from the turbulence imposed by the agitators. The baffle plate height was 6.75 inches above the top surface of the strainer top hats and 24 inches below the water surface. With this tank configuration, debris in the test tank can remain agitated and suspended without affecting the morphology of a debris bed on the strainer array.

16. Please provide information that verifies that the debris preparation and introduction methods used during the thin bed testing for the top hat strainer design were prototypical with respect to the plant-specific debris generation and transport evaluation for Catawba. Note that for thin bed testing, the NRC staff considers it prototypical or conservative for fine fiber to arrive at the strainer prior to less transportable debris. Overly coarse debris preparation or nonprototypical introduction to the flume may non-conservatively affect the potential for thin bed formation.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation.

As identified in the Preface of this submittal, prior to the Chemical Precipitates Head Loss test series performed in February 2011, a series of conventional debris head loss tests were performed in June 2009. A portion of the conventional debris head loss testing was to determine if the Catawba ECCS sump strainer was susceptible to high head losses associated with thin bed formation. In order to accomplish this, all particulate debris (i.e., destroyed coating surrogate and latent dirt surrogate) was introduced into the test tank and allowed to circulate. A small amount of fiber was then introduced into the tank and allowed to circulate. Once sufficient time was allowed for the dP across the strainer to stabilize, another fiber increment was added and again, there was a stabilization period. A borescope was used to determine if the strainer array was completely covered between increments. If a sufficient amount of particulate was filtered out of the tank mixture by the fiber bed prior to the full fiber load being introduced to the point that tank clarity improved, the test was aborted. The subsequent test then started with the same sequence; however, the initial fiber load was then made equivalent to previous total fiber that had been introduced.

Sensitivity studies were also performed to determine whether the Catawba strainers were susceptible to limiting head loss due to thin bed formation. In these studies, proportional mixtures of both fiber and particulate were introduced into the test tank simultaneously in small increments, or all at once in a bulk addition. The proportional mixture additions prevented the filtering of the particulate prior to complete strainer coverage and also facilitated the building of a more homogeneous debris bed for comparison purposes. Ultimately, it was determined through the thin bed testing that the Catawba ECCS sump strainers are not susceptible to limiting head losses due to thin bed formation when testing with conventional debris. The testing also demonstrated that utilizing a thin bed protocol results in more strainer coverage where the effect may be more problematic upon the addition of chemical precipitates.

The Chemical Precipitates Head Loss testing performed in February of 2011 was designed considering the previous conventional debris head loss testing described above. Although it had been demonstrated that the Catawba strainers were not limited by conventional debris head losses due to thin bed effects, the thin bed protocol did result in higher head losses and more complete strainer coverage compared to bulk or homogeneous debris addition. Since the thin bed protocol resulted in the highest strainer coverage and generally higher conventional debris head loss, this protocol was used for the Chemical Precipitates Head Loss testing.

Debris preparation as described in the response to RAI question 14 ensured fibrous debris was prepared appropriately with as high a percentage of fines as practical. The test tank design as described in the response to RAI question 15 ensured the prepared debris remained suspended and was transported adequately to the strainer test array. For all testing performed, Performance Contracting Inc. (PCI) dirt mix (silica dioxide) was chosen as the latent dirt surrogate and 800 grit silica carbide was used as the coatings surrogate. The pre-mixed chemical precipitate used for testing was Sodium Aluminum Silicate as prepared following the guidance and protocol outlined by WCAP-16530-NP, "Evaluation of Post- Accident Chemical Effects in Containment Sump Fluids to Support GSI-191."

17. Please provide the criteria used to judge that differential pressure-induced effects (e.g., boreholes) did not occur during testing. The existence of pressure-induced effects could invalidate the application of temperature scaling. Please state whether pressure-induced effects were identified and, if so, the resultant effect on the application of temperature scaling.

<u>Catawba Response:</u>

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information herein pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Sump Strainers.

NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the areas of Strainer Head Loss and Vortexing, dated March 2008 identifies concerns with debris bed morphology in the areas of boreholes and flow channeling. In order to accommodate shifts in debris bed morphology as it pertains to temperature/viscosity scaling of test head loss results; it is recommended to perform flow sweeps as part of the testing methodology.

For the tests of record, the protocol dictated that flow sweeps be performed as a final phase of testing after all conventional and chemical precipitate debris was added to the test tank and the strainer array differential pressure stabilized. This flow sweep data was then used to determine the laminar and turbulent fractions used for temperature scaling of the strainer head loss as described in response to RAI question 11 of this submittal.

18. Please provide the scaling parameters used for calculation of debris quantities and strainer approach velocities used during testing. Please state whether the scaling accounted for strainer areas blocked by miscellaneous debris such as labels and tape.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information below pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Strainers.

During previous testing, small amounts of fiber had been observed to bridge over the non-flowing surfaces of the strainer. It is therefore assumed that tags, labels and other miscellaneous latent debris that transport to the strainer may also overlap the non-flowing areas as well. The strainer area then used to base debris scaling becomes the gross strainer area of the limiting Catawba strainer (i.e. smallest surface area, Unit 2) minus an area penalty for tags and labels as discussed in response to RAI question 10 of this submittal. Approach velocity is scaled based on the same methodology as above with the exception of an additional 3% void fraction penalty at the strainer surface.

Catawba has implemented an ECCS water management initiative on both units. Thus, the scaled flow is equivalent to 12,000 gpm representing two Residual Heat Removal pumps and One Containment Spray pump. This flow rate is assumed for the entire 30 day mission time of the ECCS sump strainer and no credit is taken for reducing ECCS flow later in the mission time. It should be noted that the penalties associated with blockage due to tags, labels and trash were not further refined with the adoption of ECCS water management. As reported in response to RAI question 13 of this submittal, the area penalty associated with tags and labels is $586 ft^2$ with an overlap of 25% for a totally blocked area of $440 ft^2$. This blockage penalty was originally calculated based on a pre-water management ECCS flow of 16,000 gpm. It is likely there would be less transport of these materials to the strainer with ¾ the overall flow to the strainer.

19. Please discuss the NRC staff's observation that in the IPT the flow was non-prototypically directed at the top hat strainer in a direction parallel to the top hat long axis. Please address whether this non-prototypical flow direction could result in a non-prototypical formation of debris on the top hat strainer.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information herein pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Strainers.

Details on debris preparation and transport are provided in the response to RAI question 14 of this submittal. Details on the test tank utilized for ECCS Strainer performance testing are described in detail in the response to RAI question 15 of this submittal.

20. Please provide the clean strainer head loss for Catawba Unit 1 (only the clean strainer head loss for Catawba Unit 2 was provided).

Catawba Response:

For completeness, the clean strainer head loss for both Catawba Units 1 and 2 are provided:

The Catawba Unit 1 clean strainer head loss, based on the installed strainer area and configuration at 60°F, is calculated as 2.94 feet of water for the maximum recirculation flow condition.

The Catawba Unit 2 clean strainer head loss, based on the installed strainer area and configuration at 60°F, is calculated as 2.78 feet of water for the maximum recirculation flow condition.

It should be noted that the clean strainer head loss numbers stated above are lower than values reported in previous submittals. This is based on implementation of ECCS Water Management. This lowers the overall flow through the strainer by only relying on one train of containment spray as opposed to two. Thus, overall flow through the strainer is reduced by 25% which in turn reduces the clean strainer head loss.

21. Please provide the time-dependent results and calculation methodology for determining net positive suction head (NPSH) margin throughout the 30-day mission time.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information herein pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Strainers.

NPSH margin throughout the 30-day mission time is discussed in detail in RAI question 25 of this submittal.

22. Please provide the basis for the debris introduction information that indicates that no 'fine fibrous debris would be generated during a loss-of-coolant accident (LOCA). If the assumption of zero fibrous debris generation is in error please provide the amount of fibrous debris generated by the limiting break and justify why, in such a case, the head loss test results would remain valid.

Catawba Response:

Please reference the response to RAI question 4 of this submittal for the details regarding Zones of Influence (ZOI) for Low Density Fiberglass (LDFG) Insulation, fiber size distribution for destroyed LDFG within the ZOI, and transport quantities of the destroyed insulation.

23. Please provide the types and amounts of debris added to each test (Array and IPT) and include information on introduction sequence. Please provide relevant test parameters such as temperature, debris introduction times, and flow rate for the Array and IPT tests.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on 11/24/08 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information below pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Strainers.

The scaling of debris is discussed in the response to RAI question 18. The chemical precipitates testing was conducted by initially building a conventional debris bed of particulate and fibrous debris as described in the response to RAI question 16. The total debris mix is given below in Table 23S-1.

Table 23S-1: Conventional Debris Bed Constituents

Plant Debris	Surrogate	Plant Quantity	Scaled Test Quantity
Latent Dirt	PCI dirt mix	170lbm	5.19lbm
Fibrous Debris (including latent)	Boiled Nukon Fiber	67.22ft^3	2.07ft^3 (4.96lbm)
Failed Coatings	800 grit Silica Carbide	3.74ft^3	0.114ft^3

The debris bed was built by introducing all particulate debris into the tank and allowing ample time for circulation. The fiber was introduced into the test tank in three equivalent batches. Pauses were incorporated between fiber batches to allow the head loss across the strainer test array to stabilize. The system was then allowed to stabilize a final time prior to introduction of the chemical precipitate.

The pre-prepared chemical precipitate was generated per the guidance contained in WCAP-16530-NP-A, "Evaluation of Post- Accident Chemical Effects in Containment Sump Fluids to Support GSI-191." A total of 1,402 grams of Sodium Aluminum Silicate was prepared and added to the test tank. This total was divided into four separate batches and the strainer dP was allowed to stabilize between batch additions.

The flow rate for the testing simulated a full ECCS Safeguards flow of 12,000 gallons per minute per the ECCS Water Management Initiative modifications. The scaled flow in the test tank was 378 gpm. After the final dP stabilization, a series of flow sweeps was performed to gain insights into bed behavior and to develop relationships for temperature scaling. The test tank was maintained at 90 degrees F for the duration of all testing.

24. Please provide information on the amounts of debris that settled during testing for each test (IPT, Array, and Thin Bed). Note that Enclosure 1 of supplemental response dated February 29, 2008, stated that near-field settling was not credited during testing. However, the NRC staff observed significant settling during the IPT. Please provide a quantitative evaluation of how this settling affected head losses for each test. Please state whether this settling is prototypical of plant conditions and provide a basis for the conclusion.

Catawba Response:

Near field settling is not credited in the performance evaluation of the Catawba ECCS sump strainers.

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on 11/24/08 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information herein pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Strainers.

Details on debris preparation and transport are provided in the response to RAI question 14 of this submittal. Details on the test tank utilized for ECCS Strainer performance testing are described in detail in the response to RAI question 15 of this submittal.

25. The supplemental response stated that the head loss across the Catawba Emergency Core Cooling System Sump strainer (clean strainer head loss plus debris bed head loss) is conservatively predicted to be 5.4 ft at switchover to sump recirculation. However, no explanation was provided as to how this value was derived. It appears that credit was taken for time-dependency in head loss, since the 30-day value is 8.2 ft. Please provide the time dependent results and calculation methodology for determining NPSH margin throughout the 30-day mission time.

Catawba Response:

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information below pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Sump Strainers.

Due to the redesign of the strainer tests between 2007 and 2011 as described in the preface of this submittal, the RAI question from the staff as written above in response to the 2008 Catawba Generic Letter 2004-02 Supplemental Response dated 2/29/08 (as amended by submittal dated 4/30/08) no longer applies in the same manner as it was originally intended. The primary difference is that the strainer head loss result is no longer determined from a combination of two tests; the Chemical Precipitates Head Loss test series was comprehensively designed (with technical staff input) to simplify the certification process. To provide fidelity the series consisted of two Catawba strainer tests, with the bounding test documented as the test of record. Since this RAI question is clearly focused on identifying the ECCS recirculation pump NPSH requirements as a function of the mission time (and information regarding the methodology used to determine it), that will be the approach used to respond to Catawba RAI question 25. This general approach to all of the testing-related RAI questions was discussed and agreed to with the technical staff on the September 1, 2009 public telecon between Duke and NRC.

The response to RAI question 11 of this submittal tabulates the predicted post-accident ECCS Sump Strainer head loss as a function of sump pool temperature and approximate ECCS mission time, and explains the calculation methodology used in generating it. Table 25S-1 below duplicates that head loss information, and further identifies the predicted ECCS recirculation pump NPSH margin and the ECCS Sump Strainer structural margin over the ECCS mission time for the bounding Catawba unit.

Table 25S-1

Catawba ECCS Sump Strainer Predicted Post-LOCA Head Loss and Margins

ECCS Sump Pool Temperature (°F)	ECCS Mission time (approx.)	Total ECCS Sump Strainer Head Loss (ft-water)	Limiting ECCS Recirculation Pump $NPSH_R$ Margin (ft-water)	ECCS Sump Strainer Structural Margin (ft-water)
199	0 min	6.30	**2.45**	9.93
190	8 min	6.38	**6.89**	9.85
180	22 min	6.47	11.04	**9.75**
170	50 min	6.58	14.45	**9.64**
160	1.2 days	9.99	13.94	**6.23**
140	3.5 days	10.50	17.73	**5.72**
120	16 days	11.15	19.85	**5.07**
100	>25 days	12.03	20.69	**4.19**
90	>25 days	12.70	20.61	**3.52**

Table Notes:

- Values are for the limiting Catawba ECCS Sump Strainer in Unit 2
- Limiting ECCS recirculation pump is Containment Spray (assumes minimum predicted sump pool level exists at manual initiation of Containment Spray pump)
- Assumes Maximum Safeguards conditions (three-train ECCS flowrate)
- "ECCS Mission Time" begins at swapover to sump recirculation phase

Note in the above table that, as the sump pool temperature cools, the limiting margin for the Catawba ECCS components shifts from the recirculation pump NPSH to the strainer structural limit (in Table 25S-1, the limiting values are denoted in bold type). This is a result of both the increasing density of the pool liquid at lower temperatures (benefitting available pump NPSH) and the additional increase in head loss below 165°F due to chemical precipitates acting on the conventional strainer debris bed as described in the response to RAI 11 of this submittal.

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

Methodology

Calculation of the ECCS recirculation pump NPSH margin and the ECCS Sump Strainer structural margin is a straightforward process once the total strainer head loss is known as a function of pool temperature/mission time. The basic expression for determination of the applicable ECCS recirculation pump NPSH margin at any pool temperature is:

$$\text{Total NPSH margin} =$$

$$(NPSH_A - NPSH_R) + \textit{strainer submergence} - \textit{strainer head loss}$$

Where:

$NPSH_A$ = available NPSH afforded by ECCS system piping in limiting configuration at predicted ECCS flowrate

$NPSH_R$ = required NPSH at recirculation pump impeller suction centerline at predicted ECCS flowrate

Strainer submergence = minimum predicted sump pool level at manual initiation of Containment Spray (4 feet of water at Catawba)

Strainer head loss = total head loss across strainer at three-train ECCS flowrate

Similarly, for the strainer structural margin:

$$\text{Total structural margin} =$$

$$\textit{Strainer structural limit} - \textit{strainer head loss}$$

Where:

Strainer structural limit = design limit for loaded strainer at three-train ECCS flowrate

Strainer head loss = total head loss across strainer at three-train ECCS flowrate

For convenience, Table 25S-2 below summarizes the ECCS recirculation pump NPSH requirements and the ECCS Sump Strainer structural limit

Table 25S-2

Catawba ECCS Recirculation Pump/Sump Strainer Limits

ECCS Component	$NPSH_R$/Limit
Containment Spray Pumps*	≥ 19 feet-water $NPSH_R$
Residual Heat Removal Pumps*	≥ 16 feet-water $NPSH_R$
ECCS Sump Strainer Structure**	< 16.22 feet-water total head loss

* $NPSH_R$ at room temperature and predicted ECCS flowrate. No credit is taken for $NPSH_R$ reduction at higher sump pool temperatures.

** Structural limit based on 7 psid maximum differential pressure; also reference response to RAI 27 of this submittal.

26. Please state whether the containment cleaning actions described in Duke's response to Bulletin 2003-01, sent by letter dated August 7, 2003, will remain in effect at Catawba (in order to assure that debris source assumptions made as part of the GL 2004-02 resolution remain valid). Specifically, please identify the procedures which control the cleanliness actions for containment and any commitments regarding the long-term applicability of these procedures.

Catawba Response:

As identified in the Catawba GL 2004-02 Supplemental Response dated 2/29/08, item 3(i)(1), Catawba has implemented programmatic controls to ensure that potential sources of debris that may be introduced into containment will be assessed for adverse effects on the ECCS and Containment Spray recirculation functions. The programmatic controls and practices relating to containment cleanliness include:

- Containment cleaning is conducted prior to Mode 4 Restart. Extensive containment cleaning is conducted using water spray. In general, washdowns are limited to the space in lower containment that would be submerged under large break LOCA conditions. Accessible floor and wall surfaces and mechanical equipment are washed down. Localized washdowns are performed as directed by Radiation Protection Group personnel. Containment cleanliness is currently verified prior to entry into Mode 4 Restart by procedure OP/1(2)/A/6100/001 – *Controlling Procedure For Unit Startup.*
- Visual inspections of the ECCS Sump Strainer area are performed during a refueling outage in Modes 5 and 6 in order to evaluate sump availability. Catawba Work Control Directive 3.5 currently describes the process and expectations for these inspections, which are performed in accordance with PT/1(2)/A/4400/018 – *Unit 1(2) Containment Building Civil Structures Inspection.* PT/0/A/4200/002 – *Containment Cleanliness Inspection* is performed prior to Mode 4 Restart to fulfill Catawba Technical Specification (TS) Surveillance Requirement (SR) 3.5.2.8. Catawba TS SR 3.5.2.8 requires that the ECCS Sump Strainer be visually inspected every refueling outage in order to verify there are no restrictions as a result of debris, and no evidence of structural distress or abnormal corrosion present prior to declaring the Strainer operable.
- Refueling Canal cleanliness is currently verified during Mode 6 or No-Mode by an inspection controlled by procedure MP/0/B/7150/012 – *Refueling Canal Cleanliness.* The procedure is not required by TS or Selected Licensee Commitment (SLC), but is performed prior to the transition from Mode 6 to Mode 5 operations.
- In order to satisfy TS SR 3.6.15.1, the Refueling Canal Drain Valves are currently verified as locked open and unobstructed prior to entry into Mode 4 Restart by procedure PT/1(2)/A/4600/016 – *Surveillance Requirements for Unit 1(2) Startup.*
- In order to satisfy TS SR 3.6.15.2, visual verification that no debris is present in the Refueling Canal or Upper Containment that could obstruct the Refueling Canal Drains is currently performed once every 92 days per procedure PT/1(2)/A/4600/003B – *Quarterly Surveillance Items.*
- Upgrades to existing foreign material control procedures require material accountability logs to be maintained in Modes 1 through 4 for items carried into and out of containment.

These controls are currently implemented using Catawba Site Directive 3.1.2 – *Access to Reactor Building and Areas Having High Pressure Steam Relief Devices.*

- Prior to establishing containment integrity and following containment entries made after containment integrity is established, Catawba SLC 16.6.1 currently ensures that a visual inspection is performed to identify and remove any loose debris inside containment.

As identified in the Catawba GL 2004-02 Supplemental Response dated 2/29/08, item 3(i)(3), Duke Energy's modification process currently includes an administrative procedure that directs the design and implementation of engineering changes in the plant. This procedure directs that engineering changes be evaluated for system interactions. As part of this evaluation, there is direction to include consideration of any potential adverse effect with regard to debris sources and/or debris transport paths associated with the containment sump.

The containment cleanliness actions described in Duke Energy's response to Bulletin 2003-01, sent by letter dated August 7, 2003, and in Duke Energy's response to Generic Letter 2004-02, sent by letter dated September 1, 2005, are captured by the programmatic controls and practices described above.

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

27. The revised "Content Guide for Generic Letter 2004-02 Supplemental Responses," sent by letter dated November 21, 2007, Section 3k, requests a summary of structural qualification design margins for the various components of the sump strainer structural assembly. This summary should include interaction ratios and/or design margins for structural members, welds, concrete anchorages, and connection bolts as applicable. Please provide this information.

Catawba Response:

The following information is an expansion of the data provided in the February 29, 2008 Catawba response to the Section 3k information request. Figure 27S-1 and Table 27S-1 are repeated from the previous response to aid the reader. Figure 27S-1 shows a general layout of the modified strainer assembly (without the vortex suppression structure) and is representative of both Unit 1 and Unit 2.

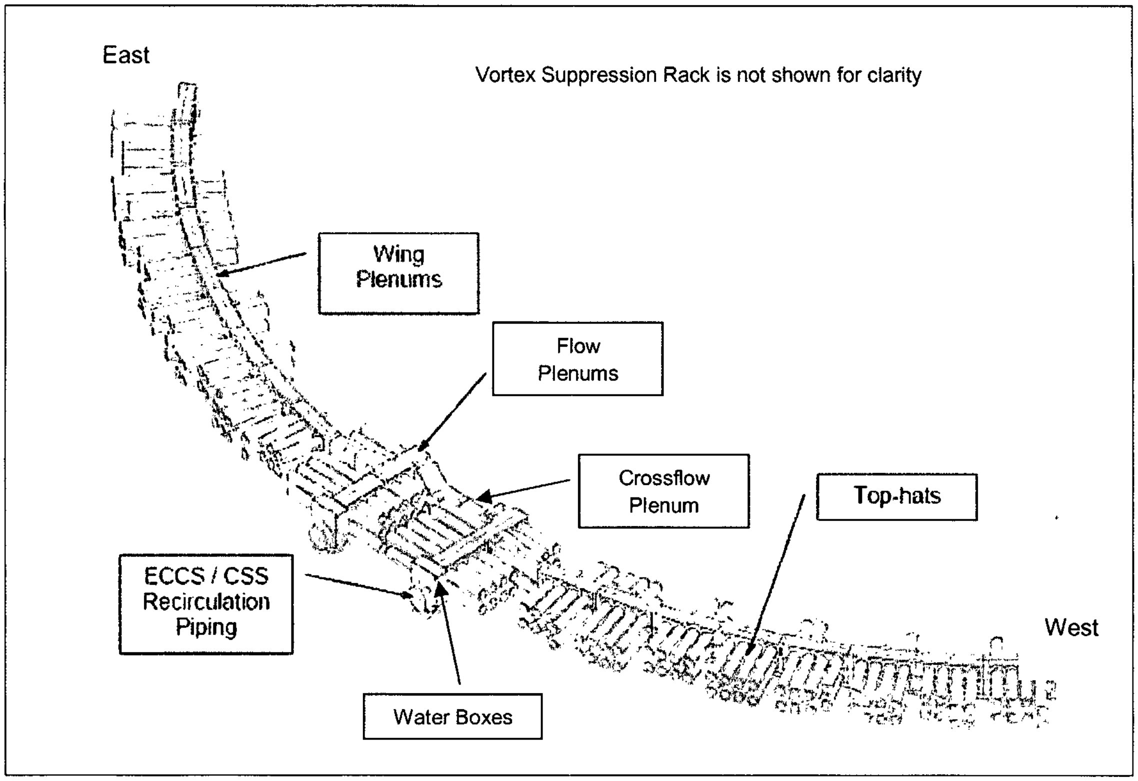

Figure 27S-1: Catawba Modified ECCS Sump Strainer

Table 27S-1 shows the design inputs for the Catawba modified ECCS sump strainer structural calculations, including the Top-hats, the Main Structure, the structure including the Wing Walls/Water Boxes, and the Vortex Suppression Rack.

Table 27S-1: Design Inputs/Loads for Catawba ECCS Sump Strainer

	Design Input	Top-hat module*	Main Structure Excluding Wing Walls/Water Boxes	Structure Including Wing Walls/Water Boxes	Vortex Suppression Rack
	Temperature	300 °F	300 °F	250 °F	250 °F
	Differential Pressure	7 psid	7 psid	7 psid	NA
	Dead Weight	0.29 lb/in^3	0.29 lb/in^3	0.29 lb/in^3	0.29 lb/in^3
	Live Load	-	-	-	50 psf
	Misc. Load (Cable Tray/Conduit)	-	-	-	27 lb/ft (U2) 160 lb (U1)
Seismic	ZPA** Frequency	20 Hz	20 Hz	20 Hz	20 Hz
	Damping	2%	2%	2%	2%
	Max SSE Horizontal Acc.	0.94 g	0.94 g	0.94 g	0.94 g
	Max SSE Vertical Acc.	0.63 g	0.63 g	0.63 g	0.63 g

*Bounding top-hat length is 45 inches for structural analysis
**Zero Potential Acceleration (ZPA)

Tables 27S-2 through 27S-5 summarize interaction ratios and/or design margins for the various Unit 1 components of the sump strainer structural assembly including structural members, welds, concrete anchorages, and connection bolts.

Table 27S-2: Analysis of Sump Strainer Top Hat				
Top Hat Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Top Hat Loading	Bending Stress	1013 psi	4509 psi	-
	Hoop Stress	373 psi	4509 psi	Axial stress is insignificant
Top Hat Buckling	Bending Moment Loading	1013 psi	24175 psi	-
	Axial Loading	118 psi	33133 psi	-
	Circumferential Pressure Loading	373 psi	1253 psi	-
3/8" Diameter Studs	Max Interaction Ration (IR)	0.07	1.0	-
Top Cover Plate	Bending Stress	2218 psi	16875 psi	-
Base Plate	Max Stress	4692 psi	16875 psi	-
1/16" Fillet Weld Between Perforated Tube and Bottom Flange	Max Force	115.29 lbs/in	563 lbs/in	Base metal shear allowable - 563 lbs/in; Fillet weld allowable - 928 lbs/in
1/16" Fillet Weld Between Perforated Tube and Cover Plate	Max Force	32.13 lbs/in	563 lbs/in	Base metal shear allowable - 563 lbs/in; Fillet weld allowable - 928 lbs/in

Table 27S-3: Analysis of Sump Strainer Structure Wing Plenums and Water Boxes				
Water Box Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Top Horizontal 3/8" Plate	Max Stress	5624 psi	16875 psi	-
3/8" Diameter Studs	Max Interaction Ration (IR)	0.15	1.0	-
Front Vertical 3/8" Plate	Max Stress	12448 psi	16875 psi	
3/8" Diameter Studs	Max IR	-	-	Acceptable as bounded by Top Horizontal Stud values
Back Vertical 3/8" Plate	Max Stress	13464 psi	16875 psi	-
3/8" Diameter Studs	Max IR	-	-	Acceptable as bounded by Top Horizontal Stud values
All Members	Max Stress IR	0.79	1.0	Faulted allowable used
1/2" Diameter Studs	Max IR	0.87	1.0	-
Welds	IR - Weld Metal Stress	0.540	1.0	-
	IR - Base Metal Shear	0.843	1.0	-
1/2" Anchor Bolts	Max IR	0.58	1.0	-
Base Plate	Max Stress	6790 psi	17813 psi	-
Middle Wing Modules Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
3/8" Plate of Tube Module	Max Stress	6869 psi	17813 psi	-
All Members	Max Stress IR	0.087	1.0	-
3/8" Diameter Studs	Max IR	0.47	1.0	-
1/2" Diameter Bolts	Max IR	0.61	1.0	-
Anchor Bolts	Max IR	0.42	1.0	-
End Wing Modules Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
3/8" Plate of Tube Module	Max Stress	6869 psi	17813 psi	-
All Members	Max Stress IR	0.246	1.0	-
3/8" Diameter Studs	Max IR	0.22	1.0	-
1/2" Diameter Studs	Max IR	0.79	1.0	-
Anchor Bolts	Max IR	0.42	1.0	-

Table 27S-4: Analysis of Sump Strainer Structure Excluding Wing Plenums and Water Boxes				
Plenum Segment				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
All Members	Max Interaction Ratio (IR)	0.575	1.0	-
	Max Stress	11830 psi	16875 psi	-
1/2" Diameter Studs	Max IR	0.51	1.0	-
1/2" Diameter Hex Bolts	Max IR	0.63	1.0	-
1/2x10x15" Plate	Bending Stress	16262 psi	16875 psi	-
Tube Steel 3x3x1/4"	Bending Stress	9096 psi	13500 psi	-
	Shear Stress	4000 psi	9000 psi	Axial stress is insignificant
Weld at Base Plate	Weld Metal Stress	0.641	1.0	-
	Base Metal Shear	1.057	1.3	Faulted allowable used
1/2" Diameter Anchor Bolts	Max IR	0.41	1.0	-
Flow Plenum Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
3/8" Plate	Stress	9600 psi	16875 psi	-
All Members	Max Interaction Ratio (IR)	0.54	1.0	-
1/2" Diameter Studs	Max IR	0.17	1.0	-
1/2" Diameter Hex Bolts	Max IR	0.1	1.0	-
1/2" Plate	Stress	15440 psi	16875 psi	-
Weld at Base Plate	Weld Metal Stress	0.107	1.0	-
	Base Metal Shear	0.177	1.0	-
Base Plate	Stress	17250 psi	20250 psi	Faulted allowable used
	Max IR	0.62	1.0	-
Cross Flow Plenum Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
17.75x45" Plate	Stress	20164 psi	21375 psi	Faulted allowable used
3/8" Diameter Bolt	Max IR	0.79	1.0	-
Miscellaneous Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Plenum End Cover Plate	Stress	7281 psi	16875 psi	-
	Max Tension Load	375 lbs	1546 lbs	Shear load is insignificant
	Max IR	0.25	1.0	-

Table 27S-5: Analysis of Vortex Suppression Rack				
Grating Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Grating	Max Load	79.5 psf	318 psf	-
1/4" Diameter Stud	Shear Load	145 lbs	229 lbs	-
Cut Grating (Bearing Bars) Around Interference	Max Interaction Ratio (IR)	0.91	1.0	Normal allowable used
Plate	Max IR	0.65	1.0	Faulted allowable used
Supporting Grating Panels	Bending Stress	1800 psi	17813 psi	Shear stress is insignificant
Welds	Weld Allowable Load	1250 lbs	3712 lbs	-
	Base Metal Shear Load	1250 lbs	2375 lbs	-
Plenum Attachment Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Angle 2x2x1/4"	Max Bending Stress	21034 psi	21375 psi	-
1/2" Diameter Bolt	Shear Load	700 lbs	1546 lbs	-
West Wing Rack Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
All Members	Max Interaction Ration (IR)	1.02	1.3	Faulted and normal allowables used
5/8" Diameter Bolts	Max IR	0.55	1.0	Faulted allowable used
5/8" Bracket Plate	Max IR	0.79	1.0	-
Welds	Max IR - Weld Metal Stress	0.758	1.0	-
	Max IR - Base Metal Shear	0.912	1.0	Faulted allowable used
3/4" Bracket Plate	Max IR	0.77	1.0	-
1" Base Plate	Max Bending Stress IR	0.76	1.0	-
3/4" Diameter Anchor Bolts	Max IR	0.88	1.0	-
1" Diameter Anchor Bolts	Max IR	0.85	1.0	-
Tube Steel 2x2x1/4"	Max Bending Stress IR	0.16	1.0	Shear stress is insignificant

East Wing Rack Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
All Members	Max Interaction Ratio (IR)	0.853	1.0	Faulted and normal allowables used
5/8" Diameter Bolts	Max IR	0.32	1.0	Faulted allowable used
5/8" Bracket Plate	Max IR	0.72	1.0	-
Welds	Max IR - Weld Metal Stress	0.753	1.0	-
	Max IR - Base Metal Shear	0.891	1.0	Faulted allowable used
1" Base Plate	Max Bending Stress IR	0.56	1.0	-
3/4" Diameter Anchor Bolts	Max IR	0.91	1.0	-

Vortex Suppression Rack Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
All Members	Max Interaction Ratio (IR)	0.893	1.0	Faulted and normal allowables used
Welds	Max IR - Weld Metal Stress	0.665	1.0	-
	Max IR - Base Metal Shear	0.967	1.0	-
5/8" Diameter Bolts	Max IR	0.42	1.0	Faulted allowable used
3/4" Bracket Plate	Max IR	0.91	1.0	Faulted allowable used
5/8" Bracket Plate	Max IR	0.99	1.0	-
Angle 2x2x1/4"	Max Bending Stress	12955 psi	14250 psi	-
1" Base Plate	Max Bending Stress IR	0.57	1.0	-
3/4" Diameter Anchor Bolts	Max IR	0.96	1.0	-

Tables 27S-6 through 27S-9 summarize interaction ratios and/or design margins for the various Unit 2 components of the sump strainer structural assembly including structural members, welds, concrete anchorages, and connection bolts.

Table 27S-6: Analysis of Sump Strainer Top Hat				
Top Hat Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Top Hat Loading	Bending Stress	1013 psi	4509 psi	-
	Hoop Stress	373 psi	4509 psi	Axial stress is insignificant
Top Hat Buckling	Bending Moment Loading	1013 psi	24175 psi	-
	Axial Loading	79 psi	33133 psi	-
	Circumferential Pressure Loading	373 psi	1253 psi	-
3/8" Diameter Studs	Max Interaction Ration (IR)	0.07	1.0	-
Top Cover Plate	Bending Stress	2218 psi	16875 psi	-
Base Plate	Max Stress	5232 psi	16875 psi	-
1/16" Fillet Weld Between Perforated Tube and Bottom Flange	Max Force	115.29 lbs/in	563 lbs/in	Base metal shear allowable - 563 lbs/in; Fillet weld allowable - 928 lbs/in
1/16" Fillet Weld Between Perforated Tube and Cover Plate	Max Force	32.13 lbs/in	563 lbs/in	Base metal shear allowable - 563 lbs/in; Fillet weld allowable - 928 lbs/in

Table 27S-7: Analysis of Sump Strainer Structure Wing Plenums and Water Boxes				
Water Box Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Top Horizontal 3/8" Plate	Max Stress	5624 psi	16875 psi	-
3/8" Diameter Studs	Max Interaction Ration (IR)	0.15	1.0	-
Front Vertical 3/8" Plate	Max Stress	12448 psi	16875 psi	-
3/8" Diameter Studs	Max IR	-	-	Acceptable as bounded by Top Horizontal stud values
Back Vertical 3/8" Plate	Max Stress	13464 psi	16875 psi	-
3/8" Diameter Studs	Max IR	-	-	Acceptable as bounded by Top Horizontal stud values
All Members	Max Stress IR	0.761	1.0	-
1/2" Diameter Studs at Bottom Plate	Max IR	0.87	1.0	-
Welds	IR - Weld Metal Stress	0.399	1.0	-
	IR - Base Metal Shear	0.861	1.0	-
1/2" Anchor Bolts	Max IR	0.48	1.0	-
Base Plate	Max Stress	6645 psi	17813 psi	-
Middle Wing Modules of Water Boxes Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
3/8" Plate of Tube Module	Max Stress	6869 psi	17813 psi	-
Members	Max Stress IR	0.087	1.0	-
3/8" Diameter Studs	Max IR	0.47	1.0	-
1/2" Diameter Bolts	Max IR	0.61	1.0	-
Anchor Bolts	Max IR	0.42	1.0	-
End Wing Modules of Water Boxes Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
3/8" Plate of Tube Module	Max Stress	6869 psi	17813 psi	-
Members	Max Stress IR	0.246	1.0	-
3/8" Diameter Studs	Max IR	0.22	1.0	-
1/2" Diameter Studs	Max IR	0.79	1.0	-
Anchor Bolts	Max IR	0.42	1.0	-

Table 27S-8: Analysis of Sump Strainer Structure Excluding Wing Plenums and Water Boxes				
Plenum Segment				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Members	Max Interaction Ration (IR)	0.575	1.0	-
	Max Stress	11830 psi	16875 psi	-
1/2" Diameter Studs	Max IR	0.51	1.0	-
1/2" Diameter Hex Bolts	Max IR	0.63	1.0	-
1/2x10x15" Plate	Bending Stress	16262 psi	16875 psi	Other stresses are acceptable since loads are small.
Tube Steel 3x3x1/4"	Bending Stress	9096 psi	13500 psi	-
	Shear Stress	4000 psi	9000 psi	Axial stress is insignificant
Weld at Base Plate	Weld Metal Stress	0.641	1.0	-
	Base Metal Shear	1.057	1.3	Since IR > 1.0, faulted allowable used
1/2" Diameter Anchor Bolts	Max IR	0.41	1.0	-
Flow Plenum Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
3/8" Plate	Max Stress	9600 psi	16875 psi	-
Members	Max IR	0.54	1.0	-
1/2" Diameter Studs	Max IR	0.17	1.0	-
1/2" Diameter Hex Bolts	Max IR	0.1	1.0	-
1/2" Plate	Stress	15440 psi	16875 psi	-
Weld at Base Plate	Weld Metal Stress	0.107	1.0	-
	Base Metal Shear	0.177	1.0	-
Base Plate	Max Stress	18864 psi	20250 psi	Faulted allowable used
	Max IR	0.931	1.0	-
5/8" Diameter Anchor Bolt	Max IR	0.8	1.0	-
Cross Flow Plenum Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
17.75x45" Plate	Max Stress	20164 psi	21375 psi	Faulted allowable used
3/8" Diameter Bolt	Max IR	0.79	1.0	-

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

Miscellaneous Evaluation				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Plenum End Cover Plate	Max Stress	7281 psi	16875 psi	-
	Max IR	0.25	1.0	-

Table 27S-9: Analysis of Vortex Suppression Rack				
West Wing Vortex Suppression Rack Structural Frame Analysis				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Member Stresses	Max Interaction Ration (IR)	0.697	1.0	Faulted and normal allowables used
1/2" Diameter Bolts	Max IR	0.61	1.0	Faulted allowable used
5/8" Clip Plate	Max IR	0.72	1.0	Normal allowable used
1/2" Clip Plate	Max IR	0.772	1.0	Faulted allowable used
1/2" Plate	Max Bending Stress	9120 psi	24262 psi	-
Grating	Max Shear Load	145 lbs	229 lbs	-
Angles 2x2x1/4"	Max Stress	21034 psi	21375 psi	Plenum attachment
3/4" Base Plate	Max IR – Bending Stress	0.93	1.0	-
3/4" Anchor Bolts	Max IR	0.95	1.0	-
Welds	Max IR - Weld Metal Stress	0.638	1.0	-
	Max IR - Base Metal Shear	0.998	1.0	-

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

East Wing Vortex Suppression Rack Structural Frame Analysis				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Member Stresses	Max IR	0.723	1.0	Faulted and normal allowables used
1/2" Diameter Bolts	Max IR	-	-	Qualified via comparison to similar wing rack components; same loading, same IR
5/8" Clip Plate	Max IR	-	-	Qualified via comparison to similar wing rack components; same loading, same IR
1/2" Clip Plate	Max IR	0.93	1.0	-
1/2" Plate	Max Bending Stress	10080 psi	24262 psi	-
Grating	Max Shear Load	113 lbs	229 lbs	-
Angles 2x2x1/4"	Max Stress	-	-	Same loads as West Wing; therefore qualified
3/4" Base Plate	Max IR – Bending Stress	0.962	1.0	-
3/4" Anchor Bolts	Max IR	0.89	1.0	-
Welds	Max IR - Weld Metal Stress	0.810	1.0	-
	Max IR - Base Metal Shear	0.974	1.0	-

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

Main Vortex Suppression Rack Structural Frame Analysis				
Component Description	**Measurement**	**Actual**	**Allowable**	**Comments**
Member Stresses	Max IR	0.722	1.0	Faulted and normal allowables used
1/2" Diameter Bolts	Max IR	0.77	1.0	Faulted allowable used
Clip Plate	Max IR	0.97	1.0	Faulted allowable used
1/2" Plate	Max Bending Stress	23232 psi	24262 psi	-
Welds	Max IR - Weld Metal Stress	0.771	1.0	-
	Max IR - Base Metal Shear	0.995	1.0	-
Grating	Max Tension Load	667 lbs	720 lbs	On short cantilevered section
Angles 2x2x1/4"	Max Tension Load	333 lbs	1604 lbs	Water Box attachment
3/4" Base Plate	Max IR – Bending Stress	0.84	1.0	-
3/4" Anchor Bolts	Max IR	0.86	1.0	-

28. Please describe the basis for concluding that there is no potential of debris blockage at the ice condenser drains and refueling canal drains for accident scenarios where containment spray is necessary.

Catawba Response:

In addition to the programmatic controls regarding containment and refueling canal cleanliness described in the Catawba response to RAI question 26, Catawba has implemented the following programmatic controls regarding ice condenser cleanliness:

- The ice condenser is inspected for foreign material prior to the transition from Mode 5 to Mode 4 Restart. Any debris that cannot be removed is evaluated by the Containment Sump Engineer prior to entering Mode 4.
- In order to fulfill Technical Specification (TS) Surveillance Requirement (SR) 3.6.15.3, ice condenser floor drains are verified as operable once every 18 months during shutdown. All four of the following items must be verified for the ice condenser floor drains to be considered operable:
    1. Flapper valve opening is not impaired by ice, frost, or debris
    2. Flapper valve seat shows no evidence of damage
    3. Flapper valve opening force does not exceed a prescribed value
    4. Drain line from the ice condenser floor to the lower compartment is unrestricted.

The programmatic controls prevent debris blockage at the ice condenser and refueling canal drains prior to an accident. In order to reach and potentially block the refueling canal floor drains, any debris created during an accident in lower containment would have to be carried by blowdown flow up through the congested areas around the Pressurizer, the steam generator RCS nozzles, lower lateral supports and lower barrel, into the ice condenser Lower Plenum, and then navigate a torturous path through the ice condenser baskets into upper containment. This is not a credible scenario.

The ice condenser floor drain check valves are initially held closed by the blowdown pressure in the lower compartment, preventing any debris from directly entering the drain lines. Any debris that might enter the ice condenser Lower Plenum via the high velocity blowdown flowstream through the inlet portals would initially be carried up into the ice bed and become trapped; it would then have to navigate a torturous path back down through the basket array and lattice frames in order to challenge the ice condenser floor drains. As described in Section 3(I)(1) of the Catawba GL 2004-02 Supplemental Response dated 2/29/08, even if this were to occur, by design ice melt and any spray flow in the ice condenser Lower Plenum during postulated accident scenarios will flow laterally from Bay to Bay to the available floor drains as well as out of the open Lower Inlet Doors.

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC RAI
Final Response

29. The NRC staff considers in-vessel downstream effects to not be fully addressed at Catawba, as well as at other pressurized-water reactors. The supplemental response for Catawba refers to the evaluation methods of Section 9 of Topical Report (TR) WCAP-16406-P, Revision 1,"Evaluation of Downstream Sump Debris Effects in Support of GS-191,"forinvessel downstream evaluations and makes reference to a comparison of plant-specific parameters to those evaluated in TR WCAP-16793-NP, Revision 0, "Evaluation of Long Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final Safety Evaluation (SE) for TR WCAP-16793NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for Catawba by showing that the licensee's plant conditions are bounded by the final TR WCAP-16793-NP and the conditions and limitations identified in the final NRC staff's SE. The licensee may also resolve this item by demonstrating without reference to TR WCAP16793 or the NRC staff's SE that in-vessel downstream effects have been addressed at Catawba. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff's SE on TR WCAP-16793. The NRC staff is developing a Regulatory Issue Summary to inform the industry of the NRC staff's expectations and plans regarding resolution of this remaining aspect of GSI-191.

Catawba Response:

Catawba Nuclear Station will address the in-vessel downstream effects issue within 90 days of issuance of the staff's final Safety Evaluation on TR WCAP-16793.

30. Please discuss why the Integrated Prototype Test (IPT) provided a representative debris bed on the top-hat strainer module for filtering chemical precipitates. The NRC staff observed the debris addition video and concluded that the fibrous debris introduced into the test tank was more agglomerated than what may arrive at the strainer under post-LOCA flow conditions in the plant. Is the amount of bare strainer area observed in the test representative of what is expected to occur with the plant strainer array if a large break LOCA were to occur? The use of chemical effects test results derived from a test which formed a non-prototypically partially clean screen fiber bed would not be appropriate.

<u>Catawba Response:</u>

NRC technical staff concerns with the Array Test and the Integrated Prototype Test (debris preparation, debris introduction, debris agglomeration, flow fields, bare strainer area and chemical effects) were discussed at the public meeting convened on November 24, 2008 in Washington, D.C. It was determined that resolution of the issues raised by the staff at that meeting would require further testing and evaluation. As stated previously in this submittal, the information herein pertains to the Chemical Precipitates Head Loss test series performed in February 2011, which is the test of record for the Catawba ECCS Strainers.

Catawba has not attempted to predict or characterize the amount of bare strainer that could exist post-LOCA. The thin bed testing protocol (as detailed in RAI 16 of this submittal) was used during the Chemical Precipitates Head Loss testing in accordance with the NRCs Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008, in order to promote strainer coverage and increased head losses.

The preparation and introduction of debris is discussed in the responses to RAI questions 14 and 16 of this submittal. Test tank design and transport of debris in the test tank is discussed in the response to RAI question 15 of this submittal.

Attachment 3

Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC Request for Additional Information

Commitments

August 13, 2012

Attachment 3
Catawba Nuclear Station
Generic Letter 2004-02 Supplemental Response
11/21/08 NRC Request for Additional Information

Commitments

August 13, 2012

Commit. #	RAI Resp.#	Commitment	Due Date
1	29	Catawba will address the in-vessel downstream effects issue.	Within 90 days of issuance of the staff's final Safety Evaluation on TR WCAP-16793.