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March 25, 2009

U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: Document Control Desk

Subject: Duke Energy Carolinas, LLC (Duke)
McGuire Nuclear Station, Units 1 and 2
Docket Nos. 50-369 and 50-370

Response to Request for Additional Information Related to the License Amendment Request (LAR) for Implementation of Alternative Source Term (AST)

This letter provides the responses to the fourth request for additional information (RAI) regarding the AST LAR. The request was conveyed by the NRC staff via electronic mail from Jon Thompson on March 17, 2009. The NRC staff's questions and Duke's responses are provided in Attachment 1.

The conclusions reached in the original determination that the LAR contains No Significant Hazards Considerations and the basis for the categorical exclusion from performing an Environmental/Impact Statement have not changed as a result of this request for additional information.

Please contact Lee A. Hentz at 704-875-4187 if additional questions arise regarding this license amendment request.

Sincerely,

Bruce Hamilton

Bruce H. Hamilton

Attachment

A001
NRR

cc: w/attachment

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OATH AND AFFIRMATION

Bruce H. Hamilton 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.

Bruce Hamilton

Bruce H. Hamilton, Site Vice President

Subscribed and sworn to me: March 25, 2009

Date

Tori C. Gibby

Notary Public

My commission expires: July 1, 2012

Date

ATTACHMENT 1

REQUEST FOR ADDITIONAL INFORMATION

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REGARDING PROPOSED LICENSE AMENDMENT REQUEST FOR

IMPLEMENTATION OF ALTERNATIVE SOURCE TERM

MCGUIRE NUCLEAR STATION, UNITS 1 AND 2

1. In the submittal it states that the McGuire sump pH analysis used the same methodology/PHSC macro as used for the Catawba pH analysis. Please confirm that this is the case, and state any key differences between the Catawba and McGuire calculations. Also please clarify if the Catawba assumptions were also used in the McGuire analysis. If different assumption were used, please describe the specific assumptions and the basis for the differences.

Duke Response

The McGuire Nuclear Station (MNS) and Catawba Nuclear Station (CNS) sump pH analyses use the same methodology/PHSC macro (see Sections 4.2.5 and 4.4.10 of Reference 1 for discussion of code and methodology). All assumptions and methods used to determine the sump pH were the same for both sites with the exception of the site specific inputs described below.

Reactor Coolant System Lithium Concentration

The method used to determine the amount of lithium in the reactor coolant stems from chemistry procedures and is related to the amount of boron in the reactor coolant. The cycle initial boron concentration and its letdown (decrease) over the cycle is established by the cycle design. Scoping calculations confirm that maximizing the boron concentration has more impact on sump pH than minimizing the lithium concentration. Therefore, the maximum boron concentration was established in the analysis and the corresponding lithium concentration was derived from it. The reactor coolant lithium concentration values for Catawba and McGuire are 8.53 ppm and 7.74 ppm respectively.

Reactor Coolant System Boron Concentration

The Refueling Water Storage Tank (FWST) boron concentration is also used as the Reactor Coolant (NC) System boron concentration in the analysis. The NC System boron concentration is cycle specific and is set by the core design. However, it will always be bounded by the amount of boron in the FWST, so assuming the FWST concentration is very conservative and it leads to a conservatively lower sump pH. The values for Catawba and McGuire are 3075 ppm and 2875 ppm, respectively.

Refueling Water Storage Tank Fluid Volume

This parameter reflects the total FWST volume available for injection to the Reactor Coolant System and subsequent migration to the containment sump. This volume is determined by subtracting the vortex allowance from the maximum FWST inventory and it is controlled by the Core Operating Limits Report (COLR). The values for Catawba and McGuire are approximately 319,600 gallons and 346,600 gallons, respectively.

Refueling Water Storage Tank Boron Concentration

The range of boron concentration in the FWST is specified in the COLR in accordance with Technical Specification (TS) 5.6.5. This document contains cycle specific information which could be impacted by the reload core design. The maximum value in the COLR is used for this analysis. More boron in the sump will lead to a lower sump pH, which reduces spray effectiveness and produces more conservative doses. Boron related data in the COLR has not changed for several cycles. The values for Catawba and McGuire are 3075 ppm and 2875 ppm, respectively.

Cold Leg Accumulator Volume

The Cold Leg Accumulators (CLA) at McGuire and Catawba are sized differently as reflected in Technical Specification 3.5.1 for each plant. These Technical Specifications contain a minimum and maximum CLA volume. The maximum volume was used in the sump pH analysis to provide more boron to the sump which would reduce sump pH. The CLA volumes for Catawba and McGuire are 8079 gallons and 7342 gallons, respectively. All four of CLAs in a Reactor Building are included in the sump pH model.

Cold Leg Accumulator Boron Concentration

As with the boron concentration in the FWST, this value is taken from the COLR. The maximum boron concentration value was applied, since that would supply more boron to the sump which would tend to reduce sump pH. The maximum CLA boron concentrations used in the sump pH analysis for Catawba and McGuire are 3075 ppm and 2875 ppm, respectively.

Sump Temperature

The site specific sump temperature profiles were determined in the accident response thermal/hydraulics analyses. A piecewise function was formulated for each to model its profile. Each temperature profile function was created to conservatively yield higher temperatures with respect to the predicted sump temperature profile. Higher temperature leads to lower pH, which is conservative. The Catawba and McGuire sump temperature piecewise functions used in the sump pH analyses are provided below.

Catawba

T_{sump} =	236 °F	$t \le 30$ sec
T_{sump} =	(135600 - 36t) / 570 °F	30 sec < $t \le 600$ sec
T_{sump} =	(126600 - 11t) / 600 °F	600 sec < $t \le 1200$ sec
T_{sump} =	189 °F	1200 sec < $t \le 1500$ sec
T_{sump} =	(138300 - 4t) / 700 °F	1500 sec < $t \le 2200$ sec
T_{sump} =	185 °F	2200 sec < t

McGuire

T_{sump} =	$228 - 128e^{-t}$ °F	$t < 100$ sec
T_{sump} =	$230.52 - 2.54*10^{-2}t + 2.54*10^{-6}t^2$ °F	100 sec $\le t \le 5000$ sec
T_{sump} =	167 °F	5000 sec < t

Post-Accident Gamma Radiation Dose

The maximum post LOCA one year integrated gamma dose is used as the basis for the radiation component of the model. The use of the maximum post LOCA dose in the Reactor Building is conservative as it is applied to all spaces in the Reactor Building in this analysis. The accumulated dose increases during the post LOCA period, and thus, is time dependent. The time dependency is modeled utilizing a curve representing the integrated dose with respect to time. As with the sump temperature profile, this time dependency is included in the sump pH analysis via a piecewise function. The piecewise functions for both sites are provided below.

Catawba

$D(t) = 9.197*10^{-4}t$ Mrads $t < 3600$ sec

$D(t) = 6.81[\log_{10}(t/3600)]^2 + 8.36[\log_{10}(t/3600)] + 3.31$ Mrads   3600 sec $\le t <$ 360,000 sec

McGuire

$D(t) = 7.61*10^{-4}t$ Mrads $t < 3600$ sec

$D(t) = 6.25[\log_{10}(t/3600)]^2 + 7.46[\log_{10}(t/3600)] + 2.74$ Mrads   3600 sec $\le t <$ 360,000 sec

Ice Melt Mass

The time dependent ice melt model also is derived in the post accident thermal/hydraulics analysis and is a site specific input to the sump pH calculation. The minimum total ice mass from Technical Specification 3.6.12 is used in the analysis. For McGuire, this mass is $1.89x10^6$ lbm; and for Catawba it is $2.13x10^6$ lbm. Modeling the minimum total mass is conservative because it provides the least amount of sodium tetraborate to the sump. Reducing sodium in the sump is conservative because sodium tends to increase pH in the sump. The ice melt models for Catawba and McGuire follow.

Catawba

Time (sec)	Mass of Ice Melt (lbm)
0	0
60	517,000
90	605,000
227	651,000
300	708,000
500	815,000
600	877,000
900	1,051,000
1200	1,092,000
1461	1,149,000
2000	1,297,000
2408	1,395,000
3000	1,569,000
3380	1,687,000
4000	1,836,000
5000	2,010,000
5960	2,130,000
end	2,130,000

McGuire

Time (sec)	Mass of Ice Melt (lbm)
0	0
60	653,000
160	732,000
230	770,000
450	861,000
750	968,000
1400	1,156,000
1900	1,283,000
2400	1,384,000
2900	1,478,000
3400	1,581,000
4200	1,708,000
4800	1,788,000
5400	1,843,000
6000	1,879,000
6600	1,890,000
end	1,890,000

2. Please provide the minimum and maximum water volumes for the RWST, accumulators, RCS, and ice in the ice condenser. Also provide the minimum and maximum boron concentration values for the RWST, accumulators, and RCS.

Duke Response

Similar to the response to Question 8, low pH is conservative for spray lambda modeling and its effect on dose computations. Thus, only the minimum sump pH case, which is bounding for the dose analysis, was modeled. For this case, it was only necessary to use the bounding value (either the minimum or maximum) for volumes and boron concentrations, rather than the ranges. The requested values and their justifications follow.

Refueling Water Storage Tank

The maximum FWST volume is used for the sump pH analysis. The FWST water is borated, so a larger volume of FWST water transferred to the sump provides a greater amount of boric acid to the sump which would act to lower sump pH. The total usable FWST volume for McGuire is approximately 346,600 gallons. The volume of the tank below the suction line is not available for injection to the Reactor Coolant System and subsequent migration to the containment sump.

The boron concentration in the FWST is controlled by the Core Operating Limits Report (COLR) as prescribed in McGuire Nuclear Station Technical Specification (TS) 5.6.5. The sump pH analysis utilizes the maximum boron concentration permitted in the in the COLR, 2875 ppm. As previously discussed, this provides a greater amount of boron to the sump which tends to reduce sump pH.

Cold Leg Accumulators

The CLA volume is controlled by TS SR 3.5.1.2. As with the FWST volume it is conservative to use the maximum CLA volume to provide the largest amount of boron to the sump, which acts to reduce pH. The sump pH analysis uses an accumulator volume of 7,342 gallons which is the maximum volume of a CLA permitted per TS SR 3.5.1.2. All four CLAs are included in the model.

The CLA boron concentration is controlled in the COLR (as is the FWST boron concentration as discussed previously). As with the FWST boron, the CLA boron concentration is maximized to conservatively lower pH. The maximum COLR permitted CLA boron concentration is used in the sump pH analysis, 2875 ppm.

Reactor Coolant System

Using the maximum Reactor Coolant System volume is conservative, because more boron is provided to the sump, which reduces pH. The maximum reactor coolant volume, at operating conditions, is approximately 12,000 ft^3.

The boron concentration in the Reactor Coolant System varies with the core design and the time in core life, but the NC System boron concentration is less than the FWST boron concentration during reactor operation. As a result, the NC System boron concentration is conservatively assumed to be at the FWST value.

Ice Condensers

McGuire Technical Specifications SR 3.6.12.4 and SR 3.6.12.5 prescribe the minimum total ice condenser mass and the minimum mass per basket. Modeling a larger ice mass would add more sodium to the sump, which would increase the sump pH. The impact of the sodium on sump pH more than offsets the effects of the boron in the ice condenser resulting in a net increase in sump pH. A smaller volume is, therefore, conservative. The analysis uses the Technical Specification minimum mass of 1.89×10^6 lbm.

The minimum boron concentration is used for modeling the ice contribution to the sump. This is the only parameter where the boron concentration is minimized. The boron concentration of the ice is minimized in the model because boron in the form of sodium tetraborate is in the ice. The impact on sump pH by the sodium in this compound dominates the effect of the boron. Therefore, a lower boron concentration is desired for this parameter to also minimize the sodium content. Overall, minimizing the ice sodium tetraborate concentration leads to a lower, and more conservative, sump pH. The chemical requirements for the ice are controlled by TS SR 3.6.12.2 and SR 3.6.12.7. The TS minimum permitted ice boron concentration, 1800 ppm, is used in the sump pH analysis.

3. Please clarify, in the calculation of the nitric acid, whether the dose used in the calculation was the gamma dose or the gamma and beta dose.

Duke Response

The formation of nitric acid from radiolysis was modeled based upon the maximum post LOCA gamma radiation dose from all areas of the Reactor Building. The application of this value conservatively bounds the potential for nitric acid formation in any location in the Reactor Building. As described in NUREG/CR-5950 (Reference 3), nitric acid is formed from the radiolysis of water and air. While the tests described in Table 2.1 of Reference 3 indicate the use of a Co-60 gamma source, betas could also be present in a post accident environment. The range (penetrating ability) of gammas is much greater than the range of betas. In water, the range of betas is on the order of an inch and fractions of an inch in denser materials such as concrete (Reference 4). Gammas have a much greater range and the ability to transit through larger and denser structural components in the Reactor Building. Thus, the impact of the betas would be localized and somewhat shallow, whereas gammas, from a given location, could impact a much larger portion of the Reactor Building and a much deeper depth of a pool of water. Thus, gamma radiation would be expected to be the dominant contributor to the radiolysis component of nitric acid formation.

4. Please specify the type of cable insulation McGuire has in containment (Hypalon, PVC, and/or EPR). Also, please provide the mass of the insulation used in the calculation of the HCl along with any assumptions made to determine this mass.

Duke Response

Since McGuire and Catawba are sister four loop Westinghouse ice condenser plants, there are a number of similarities between the construction of these units. It is expected that the cabling of the units at the same site and for all four units at these two sites would be similar, as well. So, a single model was derived to represent the mass and types of cable at these units, using the available data. The mass of cable insulation used in the Catawba and McGuire sump pH analyses is 16,662 lbm. This insulation includes Ethylene Propylene Rubber, Chlorosulphonated Polyethylene, Flame Retardant Cross Linked Polyethylene, and Flame Retardant Ethylene Propylene. This value was provided in the Catawba Alternative Source Term License Amendment RAI response dated September 22, 2004 (Table 1 of Reference 2).

Ultimately, the calculated sump pH is not very sensitive to the mass of cable insulation. If the cable insulation mass in the analysis (16,662 lbm) is doubled, the resulting sump pH is unchanged. If the analysis cable mass is tripled, the impact is a decrease of 0.01 for the normalized sump pH only; the sump pH at sump temperature remains unaffected. Therefore, it follows that the model appropriately reflects the impact of cable insulation on sump pH and that the mass used is reasonable given the sensitivity of the sump pH result to this parameter.

5. Please provide the minimum and maximum amounts of borax in containment. Were these values bounded by the amount of borax assumed in the pH calculations?

Duke Response

Borax (sodium tetraborate) in the Reactor Building, post LOCA, comes from the ice condensers. The response to Question 2 provided the Technical Specification prescribed range of boron in the ice condensers of 1800 ppm to 2330 ppm. Because all of the boron is of the form sodium tetraborate, the boron concentration is directly proportional to the total sodium tetraborate concentration. The minimum boron concentration was used for the sump pH analysis, because sodium tetraborate is an alkaline salt and increases sump pH. A lower sump pH is desired for conservatism, so the minimum ice boron value was used in this analysis. Application of the minimum ice boron concentration is discussed further in the response to Question 2.

6. Please clarify if hand calculations were also performed for the 30-day sump pH in the McGuire analysis like was done for the Catawba analysis. If so please describe or provide these hand calculations.

Duke Response

The hand calculation was originally discussed in the Catawba Alternative Source Term (AST) License Amendment Request review response to RAI question 5 in Reference 2. That calculation was performed using a case that bounded both Catawba and McGuire. Thus, the results and conclusions of that work are applicable to McGuire as well as Catawba. Based upon this work, the McGuire sump pH is also not expected to change significantly after approximately the first 100 hours. While the concentrations of Cl and NO_3 increase due to the increasing gamma dose at 720 hours, they are still small when compared to the concentrations of boron and sodium. The hand calculation determined Cl and NO_3 concentrations at 720 hrs from which the sump pH was determined. The difference in the sump pH between 50 hours and 720 hours was 0.15% for the sump pH at sump temperature and 0.26% for the normalized (at 25 °C) sump pH values, which is insignificant. As stated in the response to question 5 in Reference 2:

> A hand calculation of the sump pH at the end of 30 days (assumed duration of radiological consequences of the design basis LOCA) was completed. The calculation yielded a decrease of only 0.02 in the sump pH at 25°C and 0.01 in the sump pH at solution temperature compared to the values calculated at 3,000 minutes.

7. In the submittal it states that the sump pH will have "an eventual equilibrium pH of 7.8." Please specify the time the sump pH reaches 7.8.

Duke Response

At approximately 2 hours, the sump pH reaches its equilibrium value of 7.8 (two significant digits). At this point, no significant changes in the sump pH occur for the 30 day accident duration. The response to Question 6, above, includes further information regarding equilibrium pH conditions.

8. In figure 2 of the submittal, the "Corrected pH at Tsump" curve never reaches a pH of 7. Please justify the acceptability of this curve.

Duke Response

Figure 2 of Reference 1 shows three curves. These curves are similar in shape to those for Catawba (see Figure 1 to Attachment 3 of Reference 5). The sump pH results normalized to 25 °C are shown. The conservative correction for code benchmarking described in Section 4.4.10 of Reference 1 (page 24) and in response to question 4 in

Reference 2 is applied and also plotted. Except for the period where the correction is applied these two curves overlap. The normalized and corrected curve, which is the more conservative of the two curves, is used to show sump pH control to support the adoption of the iodine specie model in Reference 6.

The third curve reflects the sump pH response without normalization to 25 °C. It shows the pH response at the temperature of the fluid in the sump. This curve is a full pH unit or more below the temperature normalized curve. The data at sump temperature is used as input into the containment spray model (spray lambdas) described in Section 4.6.5 of Reference 1. While it would be expected that the spray water temperature would be reduced by the system coolers prior to being introduced into the upper containment atmosphere, computing the lambdas based upon expected sump temperature bounds any potential cooler performance issues. The application of this curve to the spray model is more conservative than the use of the curve at the standard (lower) temperature because the concentration of diatomic iodine is predicted to increase with a lower pH (Reference 3). This results in comparatively less spray effectiveness and less spray removal (smaller spray lambdas) from the containment atmosphere which results in greater activity releases and greater (more conservative) computed doses.

The response to question 3 in Reference 2 discussed the use of the pH profile at sump temperature in more detail. The following is extracted from that response (note that "Beahm et al." refers to NUREG/CR-5950 – Reference 3 of this response):

> ...sump pH values at actual solution temperatures are used in assessing the effect of sump water chemistry on the transport and release of iodine isotopes following a design basis LOCA. This conforms to the method of Beahm et al...which is used in calculations of time constants for CSS washout of iodine, and iodine partitioning from leakage of Engineered Safety Features (ESF) systems in the Auxiliary Building and RWST. This method predicts that the concentration of diatomic iodine [I_2] increases with increasing concentration of hydrogen ions [H^+] or increases with decreasing pH. The concentration of hydrogen ions increases and pH decreases with increasing solution temperature. (The concentration of hydroxyl ions [OH^-] also increases and pOH decreases with increasing solution temperature. However, the presence of pOH is not taken into account in the calculation of the production of I_2 per the method of Beahm et al.) Thus, as currently developed, the method of Beahm et al. predicts increased formation of I_2 with increasing solution temperature.

References

1. Letter from B. H. Hamilton (Duke) to U. S. Nuclear Regulatory Commission, *License Amendment Request for Full Scope Implementation of the Alternative Source Term*, March 20, 2008.
2. Letter from D. M. Jamil (Duke) to USNRC, *Duke Energy Corporation Catawba Nuclear Station, Units 1 and 2 Docket Numbers 50-413 and 50-414 Proposed Technical Specifications and Bases Amendment Technical Specification and Bases 3.6.10 Annulus Ventilation System (AVS) Technical Specification and Bases 3.6.16 Reactor Building Technical Specification Bases 3.7.10 Control Room Area Ventilation System (CRAVS) Technical Specification Bases 3.7.12 Auxiliary Building Filtered Ventilation Exhaust System (ABFVES) Technical Specification Bases 3.7.13 Fuel Handling Ventilation Exhaust System (FHVES) Technical Specification and Bases 3.9.3 Containment Penetrations Technical Specification 5.5.11 Ventilation Filter Testing Program (VFTP) TAC Numbers MB7014 and MB7015*, September 22, 2004.
3. Beahm, Lorenz, Weber, NUREG/CR-5950, *Iodine Evolution and pH Control*, ORNL/TM-12242 R3, December 1992.
4. U. S. Department of Health Education and Welfare, *Radiological Health Handbook*, Revised Edition, January 1970.
5. Letter from G. R. Peterson (Duke) to USNRC, *Duke Energy Corporation Catawba Nuclear Station, Units 1 and 2 Docket Numbers 50-413 and 50-414 Proposed Technical Specifications and Bases Amendment Technical Specification and Bases 3.6.10 Annulus Ventilation System (AVS) Technical Specification and Bases 3.6.16 Reactor Building Technical Specification Bases 3.7.10 Control Room Area Ventilation System (CRAVS) Technical Specification Bases 3.7.12 Auxiliary Building Filtered Ventilation Exhaust System (ABFVES) Technical Specification Bases 3.7.13 Fuel Handling Ventilation Exhaust System (FHVES) Technical Specification and Bases 3.9.3 Containment Penetrations Technical Specification 5.5.11 Ventilation Filter Testing Program (VFTP)*, November 25 2002.
6. U.S. Nuclear Regulatory Commission, RG 1.183, *Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors*, Original Issue, July 2000.