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CNS-15-027

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10 CFR 50.90

U.S. Nuclear Regulatory Commission (NRC)
Attention: Document Control Desk
Washington, D.C. 20555

Subject: Duke Energy Carolinas, LLC (Duke Energy)
Catawba Nuclear Station, Units 1 and 2
Docket Numbers 50-413 and 50-414
License Amendment Request (LAR) to Adopt National Fire Protection Association (NFPA) 805 Performance-Based Standard for Fire Protection for Light-Water Reactor Generating Plants
150-Day Response to NRC Request for Additional Information (RAI)
(TAC Nos. MF2936 and MF2937)

References:

1. Letter from Duke Energy to the NRC, "License Amendment Request (LAR) to Adopt National Fire Protection Association (NFPA) 805 Performance-Based Standard for Fire Protection for Light-Water Reactor Generating Plants", dated September 25, 2013 (ADAMS Accession Number ML13276A503)

2. Letter from the NRC to Duke Energy, "Catawba Nuclear Station, Units 1 and 2: Request for Additional Information Regarding License Amendment Request to Implement a Risk-Informed, Performance-Based Fire Protection Program (TAC Nos. MF2936 and MF2937)", dated November 20, 2014 (ADAMS Accession Number ML14308A037)

3. Letters from Duke Energy to the NRC, "License Amendment Request (LAR) to Adopt National Fire Protection Association (NFPA) 805 Performance-Based Standard for Fire Protection for Light-Water Reactor Generating Plants", dated January 13, 2015 (ADAMS Accession Number ML15015A409), January 28, 2015 (ADAMS Accession Number ML15029A697), and February 27, 2015 (ADAMS Accession Number ML15065A107)

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The Reference 1 letter requested NRC review and approval for adoption of a new fire protection licensing basis which complies with the requirements in 10 CFR 50.48(a), 10 CFR 50.48(c), and the guidance in Regulatory Guide (RG) 1.205, "Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants", Revision 1, dated December 2009. This LAR was developed in accordance with the guidance contained in Nuclear Energy Institute (NEI) 04-02, "Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program Under 10 CFR 50.48(c)", Revision 2.

The Reference 2 letter transmitted RAIs necessary for the NRC to continue its review of the Reference 1 LAR and the Reference 3 letters provided Duke Energy's 75-day, 90-day, and 120-day responses to the Reference 2 RAIs. The January 28, 2015 and February 27, 2015 Reference 3 letters indicated that responses to selected RAIs would be extended to 150-day and 180-day responses. The February 27, 2015 Reference 3 letter also provided the revised LAR pages, with the exception of those of Attachment J (Fire Modeling V&V). The letter indicated that these pages would be provided in the 150-day response.

The purpose of this letter is to provide the docketed response to the 150-day RAIs. Enclosure 1 to this letter provides this response. The format of Enclosure 1 is to restate each RAI question, followed by its associated response. Enclosure 2 to this letter provides the revised Attachment J (Fire Modeling V&V) LAR pages.

The conclusions of the No Significant Hazards Consideration and the Environmental Consideration contained in the Reference 1 letter are unaffected by this RAI response.

There are no regulatory commitments contained in this letter or its enclosures.

Pursuant to 10 CFR 50.91, a copy of this LAR supplement is being sent to the appropriate State of South Carolina official.

Inquiries on this matter should be directed to L.J. Rudy at (803) 701-3084.

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

Executed on March 30, 2015.

Very truly yours,

Kelvin Henderson
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LJR/s

Enclosures

xc (with enclosures):

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Enclosure 1

Response to 150-Day NRC RAIs

REQUEST FOR ADDITIONAL INFORMATION

LICENSE AMENDMENT REQUEST TO ADOPT

NATIONAL FIRE PROTECTION ASSOCIATION STANDARD 805

PERFORMANCE-BASED STANDARD FOR FIRE PROTECTION

FOR LIGHT WATER REACTOR GENERATING PLANTS

DUKE ENERGY CAROLINAS, LLC

CATAWBA NUCLEAR STATION, UNITS 1 AND 2

DOCKET NOS. 50-413 AND 50-414

By letter dated September 25, 2013, (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13276A503), Duke Energy Carolinas (Duke) submitted a license amendment request (LAR) to change its fire protection program to one based on the National Fire Protection Association (NFPA) Standard 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," 2001 Edition, as incorporated into Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Section 50.48(c). In order for the NRC staff to complete its review of the LAR, the following additional information is requested.

Fire Modeling (FM) RAI 01.l

During the audit walkdowns, the NRC staff observed significant amounts of fixed non-cable combustibles in a number of fire areas. For example, large amounts of exposed above-ground high-density polyethylene (HDPE) piping, which may be involved in specific scenarios as intervening combustibles, were observed in the turbine and auxiliary buildings. Explain how non-cable intervening combustibles (e.g., HDPE piping) were identified and accounted for in the fire modeling analyses.

Duke Energy Response:

During the plant walkdowns for the Fire PRA, cable and non-cable intervening combustibles were considered when establishing the target damage set for fire scenarios. Per the Catawba Fire Scenario Report: "To account for vertical propogation due to intervening combustibles, "cone of death" to the ceiling should be assumed unless sufficient spacing between target sets exists."

The only non-cable intervening combustible identified at Catawba with the potential to impact any fire scenario, is the installed above-ground high-density polyethylene (HDPE) piping. The existing HDPE piping was evaluated as not contributing to any Fire PRA scenarios for the following reasons:

1. **The HDPE piping in the Auxiliary Building is primarily located on the floor (i.e., it is held in brackets a few inches off the floor), is empty, and is located away from fixed ignition sources. Since transient combustibles would not be placed under the HDPE piping, if the piping could burn, it could be considered to be part of the ignition source itself. This floor level HDPE piping would not contribute any significant amount of energy to increase the zone of influence of an already evaluated transient fire.**

2. **HDPE piping in the Turbine Building and the Service Building is used in cooling water systems, and therefore, is typically filled with water during normal plant operational modes. An analysis of HDPE piping has demonstrated that, when filled with flowing water, HDPE piping is not predicted to ignite when exposed to heat fluxes up to 50 kW/m^2, which is well within the flame zone of any potential ignition source. The HDPE piping is not in the flame zone (typically 20-30 kW/m^2, *SFPE Handbook of Fire Protection Engineering*, 3rd Edition, Section 2-14 and Generic Fire Modeling Treatments Report 1SPH02902.030, Revision 0) and thus would not be a secondary combustible.**

Probabilistic Risk Assessment (PRA) RAI 02

Section 2.4.3.3 of NFPA-805 states that the PRA approach, methods, and data shall be acceptable to the NRC, RG 1.205 identifies NUREG/CR-6850 as documenting a methodology for conducting a FPRA and endorses, with exceptions and clarifications, NEI 04-02, Revision 2, as providing methods acceptable to the NRC staff for adopting a fire protection program consistent with NFPA-805. RG 1.200 describes a peer review process utilizing an associated ASME/ANS standard (currently ASME/ANS-RA-Sa-2009) as one acceptable approach for determining the technical adequacy of the PRA once acceptable consensus approaches or models have been established. The primary results of a peer review are the F&Os recorded by the peer review and the subsequent resolution of these F&Os.

Clarify the following dispositions to Internal Events F&Os and SR assessments identified in LAR Attachment U that have the potential to impact the FPRA results and do not appear to be fully resolved:

a) F&Os IE-06, DE-04 and TH-06 identify that loss of HVAC was not modeled in the PRA and that there is no room heat-up analysis to support this assumption. The dispositions to these F&Os conclude that any additional risk incurred from modeling loss of HVAC would be small and would not have a significant impact on the FPRA results or results for the NFPA-805 application. Discuss generally the evaluations performed to reach this conclusion and specifically address a) how HVAC dependencies were considered, b) the evaluations performed for the switchgear and battery rooms, and c) the cable routing sensitivity analysis performed to support this conclusion. Also, define what is meant by small and non-significant impact. The response should address small and non-significant in the context of both the RG 1.174 risk guidelines for transition and the posttransition change evaluation criteria, which is two orders-of magnitude less than the RG 1.174 risk guidelines.

Duke Energy Response:

F&Os IE-06, DE-04, and TH-06 identify that loss of HVAC was not modeled in the PRA and that there is no room heat-up analysis to support this assumption. The disposition of these F&Os for the LAR conclude that the impact of modeling HVAC in the Fire PRA would be minimal. To address the HVAC dependency in this RAI question in parts a) and b), subsequent to the LAR submittal, room heat-up analyses were performed for the switchgear rooms, battery rooms, and the control room using the GOTHIC analysis code. The sensitivity evaluation mentioned in the LAR is no longer required since a detailed analysis has been performed with GOTHIC. The room heat-up analyses were performed assuming a complete loss of HVAC. The results of these analyses show that equipment in these rooms will not be adversely impacted by the loss of HVAC over the 24-hour mission time. Therefore, there is no impact on the Fire PRA results or the NFPA 805 transition risk and there is no need to add the risk impact to RAI PRA 03. As requested in part c) of this RAI, no additional cable routing for HVAC was required.

Enclosure 2

LAR Revisions

This attachment documents the Verification and Validation (V&V) basis for the Fire PRA fire modeling applications at CNS. Plant specific fire modeling used to support the CNS Fire PRA consists of the following:

- The calculation of the main control room operator abandonment times [Calculation entitled, "CNS Fire Scenario Report"]; and
- The use of generic fire modeling treatments as applicable to develop Zones of Influence (ZOI) [Hughes Associates, Generic Fire Modeling Treatments, Project Number 1SPH02902.030, Revision 0, January 15, 2008].

Main Control Room Abandonment Report

The goal of the main control room (MCR) abandonment evaluation provided as Appendix E to the calculation entitled "CNS Fire Scenario Report" is to compute the time operators would abandon the main control room for both Units 1 and 2 using the NUREG/CR-6850 [2005] abandonment criteria for control room fire scenarios. The abandonment times are assessed for various electronic equipment fires and for ordinary combustible fires as defined by the discretized heat release rate conditional probability distributions presented in NUREG/CR-6850 [2005]. The abandonment time in the main control room is estimated by calculating the time to reach threshold values for temperature and visibility as identified by NUREG/CR-6850 [2005]. Additional abandonment tables are provided that are based on the abandonment criterion for immersion temperature as described in NUREG-0700 [2002]. The NUREG-0700 [2002] abandonment criterion is more conservative than the associated NUREG/CR-6850 [2005] criteria and is consistent with an expectation that operators immersed in an elevated temperature environment will continue to perform their duties before making a successful exit.

The focus of the MCR abandonment evaluation is on the first twenty-five minutes after ignition because the non-suppression probability (NSP) decreases to 0.001 at twenty minutes [NUREG/CR-6850, 2005]. The abandonment calculations are performed using the zone fire model Consolidated Fire and Smoke Transport (CFAST), Version 6.1.1 [National Institute of Standards and Technology (NIST) Special Publication (SP) 1026, 2009 and NIST SP 1041, 2008].

The MCR area geometry and fire parameters for the simulations fall within the model limits listed in NIST SP 1026 [2009], and NIST SP 1041 [2008]. Specifically, the vent area to enclosure volume ratio is less than two and the aspect ratio of the enclosures is less than five (for the true geometry). The physical input dimensions are adjusted to account for obstructions and boundary heat losses and the resulting model geometry has a length to width aspect ratio greater than five. However, the input geometry conserves the boundary area, room volume, and enclosure height. Therefore, a corridor flow model is intentionally avoided because the true geometry has an aspect ratio that is within the model limitations.

The verification for the CFAST model (Version 6.0.5) is documented in an attachment to Appendix E to the calculation entitled "CNS Fire Scenario Report" and is based on NUREG 1824, Volume 5 [2007]. Supplemental verification for CFAST, Version 6.0.10 is provided as an attachment to the MCR abandonment evaluation as well as in NIST SP 1086 [2008].

The validation for the CFAST model application at CNS is documented in an attachment to Appendix E to the calculation entitled "CNS Fire Scenario Report". The validation is demonstrated by showing the CFAST applications fall within the validation parameter space provided by NUREG-1824, Volumes 1 and 5 [2007] or would generate a conservative results relative to a configuration that falls within the validation parameter space.

In addition, the control room tests documented in NUREG/CR-4527, Volume 2 [1988] are used to provide additional validation basis for control room application of CFAST. Table J-1 provides a summary of the validation and verification basis for CFAST, Version 6.1.1 as applied in the MCR abandonment report.

Generic Fire Modeling Treatments Report

The generic fire modeling treatments, Revision 0 is used to establish ZOI for specific classes of ignition sources and serves as both a screening and final calculation of damage distances in the Fire PRA under NUREG/CR-6850 [2005], Sections 8 and 11. The generic fire modeling treatments document has two fundamental uses within the Fire PRA:

- Determine the ZOI inside which a particular ignition source is postulated to damage targets; and
- Determine the potential of the ignition sources to generate a hot gas layer within an enclosure that can either lead to full room burnout or invalidate the generic treatment ZOIs for a particular class of combustible materials.

The ZOI is determined using a collection of empirical and algebraic models and correlations. The potential for a hot gas layer having a specified temperature to form within an enclosure is determined using the zone model CFAST, Version 6.1.1 [NIST SP 1026, 2009 and NIST SP 1041, 2008].

Verification

The calculation development and review process in place at the time the Generic Fire Modeling Treatments was prepared included contributions from a calculation preparer, a calculation review, and a calculation approver. The responsibilities for each are as follows:

- The calculation preparer develops and prepares the calculation using appropriate methods.
- The calculation reviewer provides a detailed review of the report and supporting calculations, including spreadsheets and fire model input files. The reviewer provides comments to the preparer for resolution.
- Calculation approver provides a reasonableness review of the report and approves the document for release.

The calculation preparation occurred over a two year period ending in 2007. The review stage was conducted in 2007 at the completion of the preparation stage. The calculation was approved January 23, 2008. The approved document, the signature page, and an affidavit were transmitted to the Document Control Desk at the Nuclear Regulatory Commission in Washington, D. C. on January 23, 2008.

documentation and basis of the flame height correlation is Heskestad [1981] as noted in Table J-2 of this attachment. Although there are earlier forms of the flame height equation, Heskestad provides a link between the flame height and plume centerline temperature calculation and identifies the range over which the plume equations are applicable. Because the flame height and plume centerline temperature equations are linked, the plume centerline range cited by Heskestad applies to the flame height calculation as well. The plume centerline temperature equations, and thus the flame height correlation, is applicable over the following range as noted in Table J-2 [Heskestad, 1981; Heskestad, 1984]:

$$5 \lesssim \log_{10}\left[\left(\frac{c_p T_\infty}{g\rho_\infty\left(\Delta H_c/_r\right)^3}\right)\frac{\dot{Q}^2}{D^5}\right] \lesssim 5 \qquad \text{(J-1)}$$

where c_p is the heat capacity of ambient air (kJ/kg-K [Btu/lb-°R]), T_∞ is the ambient temperature (K [°R]), g is the acceleration of gravity (m/s² [ft/s²]), ρ_∞ is the ambient air density (kg/m³ [lb/ft]), $\dot{Q}$ is the fire heat release rate (kW [Btu/s), r is the stoichiometric fuel to air mass ratio, D is the fire diameter (m [ft]), and ΔH_c is the heat of combustion of the fuel (kJ/kg [Btu/lb]). Application of Equation (J-1) depends on the fuel as well as a non-dimensional form of the fire heat release rate (fire Froude Number). In practice, the heat of combustion to air fuel ratio for most fuels will fall between 2,900 – 3,200 kJ/kg (1,250 – 1,380 Btu/lb), and for typical ambient conditions the $\frac{\dot{Q}^2}{D^5}$ ratio for which the plume equations have validation basis is between 7 – 700 $kW^{2/5}/m$ (4 – 9 $Btu^{2/5}/ft$) [Heskestad, 1984]. For fire sizes on the order of 25 kW (24 Btu/s) or greater, this means that the plume centerline equation is valid for heat release rates of 100 kW/m² (8.81 Btu/s-ft²) to well over 3,000 kW/m² (264 Btu/s-ft²). For weaker fires (heat release rates less than 100 kW/m² (8.81 Btu/s-ft²), the tendency of the model is clearly to over-predict the temperature and flame height; thus for applications outside the range but below the lower limit the result will be conservative. The concern is therefore entirely on the upper range of the empirical model. The tables in the "Generic Fire Modeling Treatments" are specifically developed with transient, lubricant spill fires, and electrical panel fires with a heat release rate per unit area within the validation range. When the heat release rate per unit area falls outside the applicable range, the table entry is not provided and it is noted that the source heat release rate per unit area is greater than the applicable range for the correlations. This applies to the flame height and the plume temperature for axisymmetric source fires.

The flame height and plume centerline temperature for line type fires (fires having a large aspect ratio) are applied only to cable tray fires. The correlation used has pedigree and has existed in its general form since at least Yokoi [1960]. Most recently, Yuan et al. [1996] provided a basis for the empirical constant using experimental data with source fires having a width of 0.015 m – 0.05 m (0.05 – 0.15 ft) and a length of 0.2 – 0.5 m (0.7 – 1.5 ft) [Yuan et al., 1996]. When normalized, the applicable height to heat release rate per unit length range ($\frac{Z}{\dot{Q}'}$) for the correlations based on the experiments of Yuan et al. [1996] is between 0.002 and 0.6. This range includes the flame height as well as the elevation at which the temperature is between 204 – 329°C (400 – 625°F), the temperature at which cable targets are considered to be damaged under steady observed in fully developed fires (3 – 5) [SFPE Handbook of Fire Protection Engineering, Section 2–5, 2008; SFPE Handbook of Fire Protection Engineering, Section 3–4, 2008]. However, the limiting oxygen index used in the model is zero, which forces the combustion process to use all available oxygen within the enclosure and the heat release rate to decrease to a value set by the natural ventilation oxygen inflow. The maximum temperature over the course of the fire occurs at some time prior to the oxygen being consumed in the enclosure, thus the global equivalence ratio for the data reported is based on a condition where it is less than unity and within the validation basis of NUREG-1824, Volume 1 [2007]. Further, for a given volume and fire size, an optimum ventilation condition will occur over the vent range considered. Because of potential variations in a ventilation condition, the Fire PRA uses the most adverse time over the reported range and effectively performs an optimization on this parameter.

Finally, the flame length ratio is not always met, especially for large fires postulated in small enclosures. Because sprinkler actuation and thermal radiation to targets are not computed with the CFAST model, this parameter is not an applicable metric. Rather, the plume entrainment below the hot gas layer controls the layer decent time and the concentration of soot products in the layer. This aspect of the model is not affected by the flame height to ceiling height ratio. Consequently, the application of CFAST at the CNS control room falls entirely within the NUREG-1824, Volume 1 [2007] V&V parameter space.

Additional verification V&V studies are contained in NIST SP 1086 [2008] and Tatem et al. [2004]. These studies have a broader parameter V&V space than NUREG-1824, Volume 1 [2005] and NIST SP 1086 [2008] is based in part on the methods of American Society for Testing and Materials (ASTM) E1355 [2004]. Tatem et al. [2008] provides a Navy specific V&V study, which includes an assessment of CFAST, Version 3.1.7 predictions in multiple enclosures and multiple elevation configurations. These additional V&V studies extend the range of the V&V parameter space to include configurations and conditions applicable to the MCR abandonment sensitivity analysis (Appendix B of the "Generic Fire Modeling Treatments" report).

Appendix B of the "Generic Fire Modeling Treatments" report provides an in depth analysis of the parameters used as input and Table B–2 indicates the basis for the input parameter selection. The parameters are either selected as absolutely bounding over the credible range or establish an application limit (e.g., elevated temperature environment and boundary thermal properties).

A summary of the validation basis for both the CFAST and the empirical models is provided in Tables J-1 and J-2 of this attachment. Based on the information in the tables and the preceding discussion, it is shown that that the empirical fire model applications in the "Generic Fire Modeling Treatments" either fall within the original correlation bounds or they are outside the bounds but used in a way that is demonstrably conservative. Likewise, CFAST is used within the model limitations described in the User's Guide [NIST SP 1041, 2008] and the Technical Reference Guide [NIST SP 1026, 2009]. The results as reported in the "Generic Fire Modeling Treatments" document are based on conditions that meet the NUREG-1824, Volumes 1 and 5 V&V parameter space, although there are input specifications that fall outside this range. The use of the "Generic Fire Modeling Treatments" in the Fire PRA performs an optimization over the ventilation fraction and necessarily is based on a condition that falls within the NUREG-1824, Volumes 1 and 5 V&V parameter space for the global equivalence ratio.

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