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2CAN011401

January 6, 2014

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

SUBJECT: Response to Request for Additional Information
Adoption of National Fire Protection Association Standard NFPA-805
Arkansas Nuclear One, Unit 2
Docket No. 50-368
License No. NPF-6

REFERENCES:

1. Entergy letter dated December 17, 2012, *License Amendment Request to Adopt NFPA-805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)* (2CAN121202) (ML12353A041)
2. NRC letter dated September 11, 2013, *Arkansas Nuclear One, Unit 2 – Request for Additional Information Regarding Adoption of National Fire Protection Association Standard NFPA-805* (TAC No. MF0404) (2CNA091301) (ML13235A005)
3. Entergy letter dated November 7, 2013, *Response to Request for Additional Information – Adoption of National Fire Protection Association Standard NFPA-805* (2CAN111301) (ML13312A877)
4. Entergy letter dated December 4, 2013, *Response to Request for Additional Information – Adoption of National Fire Protection Association Standard NFPA-805* (2CAN121302) (ML13338A432)

Dear Sir or Madam:

By letter dated September 11, 2013 (Reference 2), the NRC requested additional information associated with the Entergy Operations, Inc. (Entergy) request to amend the Arkansas Nuclear One, Unit 2 (ANO-2) Technical Specifications (TS) and licensing bases to comply 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." The amendment request followed Nuclear Energy Institute (NEI) 04-02, "Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program under 10 CFR 50.48(c)." The submittal (Reference 1) described the methodology used to demonstrate compliance with, and transition to, National Fire Protection Association (NFPA)-805, and included regulatory evaluations, probabilistic risk assessment (PRA), change evaluations, proposed modifications for non-compliances, and supporting attachments.

Based on the complexity of the questions included in the Reference 2 RAI, the NRC established response due-dates of 60, 90, or 120 days, from the date of the Reference 2 letter. Entergy letter dated November 7, 2013 (Reference 3), provided the 60-day RAI responses, one 90-day Fire Modeling RAI response, and four 90-day PRA RAI responses. Entergy letter dated December 4, 2013 (Reference 4), provided the 90-day responses. Enclosed are responses to questions having a 120-day response requirement.

Changes or additional information, as detailed in this letter, with respect to the original Entergy request (Reference 1) have been reviewed and Entergy has determined that the changes do not invalidate the no significant hazards consideration included in the Reference 1 letter.

In accordance with 10 CFR 50.91(b)(1), a copy of this application and the reasoned analysis about no significant hazards consideration is being provided to the designated Arkansas state official.

This letter contains one new commitment (reference Attachment 2 of this submittal).

If you have any questions or require additional information, please contact Stephenie Pyle at 479-858-4704.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on January 6, 2014.

Sincerely,

ORIGINAL SIGNED BY JEREMY G. BROWNING

JGB/dbb

Attachments:

1. 120-Day Responses to Request for Additional Information – ANO-2 Transition to NFPA-805
2. List of Regulatory Commitments

cc: Mr. Marc L. Dapas
Regional Administrator
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NRC Senior Resident Inspector
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Attachment to

2CAN011401

120-Day Responses to Request for Additional Information
ANO-2 Transition to NFPA-805

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
ANO-2 Transition to NFPA-805

By letter dated September 11, 2013 (Reference 2), the NRC requested additional information associated with the Entergy Operations, Inc. (Entergy) request (Reference 1) to transition the Arkansas Nuclear One, Unit 2 (ANO-2), fire protection licensing basis to National Fire Protection Association (NFPA) Standard NFPA-805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)*. Entergy letter dated November 7, 2013 (Reference 3), provided the 60-day responses plus four of the 90-day responses. Entergy letter dated December 4, 2013 (Reference 4), provided the remaining 90-day responses. Enclosed are responses to questions having a 120-day response requirement. The respective question is included for convenience.

Note: All Fire Protection Engineering (FPE), Programmatic, and Radioactive Release responses associated with the aforementioned RAI were submitted in Entergy's 60-day response letter (Reference 3). Remaining Safe Shutdown Analysis (SSA) responses were submitted in the Entergy 60- and 90-day response letters (References 3 and 4).

Fire Modeling

Note: Fire Modeling RAIs 02, 03, and 05 responses were submitted in Entergy's 60-day response letter (Reference 3).

<u>Fire Modeling RAI 01</u>

NFPA-805 Section 2.4.3.3, states, "The PSA [probabilistic safety assessment] approach, methods, and data shall be acceptable to the AHJ [authority having jurisdiction] ...." The NRC staff noted that fire modeling comprised the following:

- The Consolidated Fire Growth and Smoke Transport (CFAST) model was used to calculate control room (CR) abandonment times and to evaluate development and timing of hot gas layer conditions in selected fire zones.
- Heskestad's plume temperature correlation was used to determine Severity Factors.
- The Generic Fire Modeling Treatments (GFMT) approach was used to determine the zone of influence (ZOI) in all fire areas throughout plant.
- FLASH-CAT for calculating fire propagation in stacks of horizontal cable trays.
- HEATING 7.3 was used in the assessment of the fire resistance of conduit embedded in concrete to justify exclusion of such conduit from fire zones.

LAR Section 4.5.1.2, "Fire PRA" states that fire modeling was performed as part of the Fire PRA development (NFPA-805 Section 4.2.4.2). Reference is made to LAR Attachment J, "Fire Modeling V&V [verification and validation]," for a discussion of the acceptability of the fire models that were used.

Specifically regarding the acceptability of CFAST for the CR abandonment time study:

a) Please provide the basis for the assumption that the fire brigade is expected to arrive within 15 minutes. In addition, describe the uncertainty associated with this assumption, discuss possible adverse effects of not meeting this assumption on the results of the fire PRA and explain how possible adverse effects will be mitigated.

b) Provide technical justification for the assumption that fire spreads to adjacent cabinets in 15 minutes, and not in 10 minutes as recommended in Appendix S of NUREG/CR-6850, "Fire PRA Methodology for Nuclear Power Facilities," for the case when cables in the adjacent cabinet are in direct contact with the separating wall.

c) LAR Table H-1, "NEI 04-02 FAQs Utilized in LAR Submittal," credits FAQ 08-0052, "Transient Fires Growth Rates and Control Room Non-Suppression" (ADAMS Accession No. ML092120501, closure memo). Provide justification for using transient fire growth rates that differ from those specified in FAQ-08-0052, and discuss the effect of these deviations on the risk results (i.e., core damage frequency (CDF), large early release frequency (LERF), ΔCDF and ΔLERF).

d) Provide technical justification for applying the hot gas layer smoke concentration and temperature modifications in the analysis that resulted in the CR abandonment times used in the Fire PRA.

Response

a) The ANO-2 fire brigade response time of fifteen minutes is based on what is considered a reasonably conservative bounding response time and is consistent with response times assumed or noted at other plants within the Entergy fleet as well as at other utilities. A review of fire brigade drill reports for fire brigade drills conducted in 2011 and 2012 indicates that the fire brigade response time for fires in the general area of the Main Control Room (MCR) would be approximately 9 – 10 minutes (FBDRL-2011-28 and FBDRL-2012-02). The fire brigade drill conducted on December 1, 2011 was an announced fire drill for a hydrogen leak at the ANO-2 Turbine Generator and had a response time of 9 minutes (FBDRL-2011-28). The fire brigade drill conducted on February 23, 2012 was also an announced drill for a hydrogen leak at the ANO-2 Turbine Generator and had a response time of 10 minutes (FBDRL-2012-02). The ANO-2 Turbine Generator is on the same elevation as the MCR and similar response times are thus expected.

   The fire brigade response time is incorporated into the MCR abandonment calculation (CALC-ANO2-FP-009-00013, Rev. 1) via a change in the status of the boundary doors (closed to open), though credit for manual suppression is independent of this assumption and the fire heat release rates in the CFAST models are not reduced at the brigade arrival time. Because the MCR boundary doors may open for reasons other than fire brigade arrival, such as Operator actions or occupant egress, a value of fifteen minutes was selected as an intermediate value within the time interval considered in the calculation. Note that the Fire PRA uses the natural ventilation configuration that produces the minimum abandonment time when applied to all ignition sources, which is the closed door configuration. Because the most adverse abandonment time is used for the range of natural ventilation conditions, the uncertainty in the door open time is bounded by the use of the data provided in the MCR abandonment calculation.

For completeness, the control room abandonment calculation has been updated to include a sensitivity assessment of the model results to the time the boundary doors are assumed to open (see Section A2.2.8 of CALC-ANO2-FP-009-00013, Rev. 1). The sensitivity assessment considers the effect of opening the boundary door to the MCR between ten and twenty minutes on both the calculated abandonment times and the total probability of MCR abandonment. It is shown that opening the doors at ten minutes can reduce the total probability of abandonment time by up to 61.7 percent in all but one scenario, confirming the conservative assumption of a fifteen minute abandonment time. The one scenario in which the total probability of abandonment is shown to increase when the door is opened at ten minutes causes a 14.8 percent increase, which is not considered significant. It is also shown that opening the door at twenty minutes either does not affect the total probability of abandonment relative to the assumed fifteen-minute baseline time for opening a door or causes a decrease in the total probability of abandonment (up to 73.8 percent). Note that given that the maximum time at which abandonment can affect the non-suppression probability is 20.9 minutes, the scenarios for which the door opens at twenty minutes are nearly the same scenarios as the closed door baseline scenarios.

Based on the actual response times of the fire brigade, the use of the abandonment times in the Fire PRA, and the sensitivity of the abandonment times to uncertainty in the fire brigade arrival time, there are no known adverse effects associated with not meeting this assumption.

b) The original MCR abandonment calculation (CALC-ANO2-FP-09-00013, Rev. 0) postulated a fifteen-minute propagation between adjacent panels assuming that the conditions of NUREG/CR-6850, Appendix S, for fifteen-minute propagation would generally exist. However, in order to demonstrate that this is technically justified, detailed walkdowns are required to document the internal panel configuration. In lieu of performing these walkdowns to justify the propagation time for each specific panel configuration, the conservative generic value of ten minutes per Appendix S of NUREG/CR-6850 has been used in the updated MCR abandonment calculation (see Section 5.1.3.1 of CALC-ANO2-FP-09-00013, Rev. 1) in place of the fifteen minutes used in the original calculation.

c) The characterization of the transient fire scenarios has been revised in an updated MCR abandonment calculation (CALC-ANO2-FP-09-00013, Rev. 1) such that the scenarios are consistent with the guidance provided in NUREG/CR-6850, Supplement 1. Further, the sensitivity analysis contained in Attachment 2 has been restructured and is used to provide a basis for the baseline scenario assumptions, including the time to reach a peak heat release rate for the transient fire scenarios. It is shown in Section A2.2.4 of Attachment 2 of the updated MCR abandonment calculation that a two-minute growth rate provides a conservative result for transient fire scenarios located in the MCR area.

Because the revised transient growth rates are consistent with current NUREG guidance, it is not necessary to compute the impact on fire risk results (i.e., CDF, LERF, ΔCDF and ΔLERF) for this RAI response.

d) The basis for applying a factor to the CFAST model output in the original MCR abandonment calculation (CALC-ANO2-FP-09-00013, Rev. 0) was to incorporate the uncertainty analysis elements described in NUREG-1934 directly into the baseline fire scenarios.

The MCR abandonment calculation has been updated and the model uncertainty analysis is provided separately in Section A2.3 of Attachment 2 of the updated MCR abandonment calculation (CALC-ANO2-FP-09-00013, Rev. 1). The updated MCR abandonment calculation no longer uses the hot gas layer smoke concentration and temperature modifications. The baseline fire scenarios reported in Section 6.1 of the updated MCR abandonment calculation (CALC-ANO2-FP-09-00013, Rev. 1) are based on the output values provided by CFAST without uncertainty modification.

Fire Modeling RAI 01 *(continued)*

Specifically regarding the acceptability of the Generic Fire Modeling Treatments approach:

e) Please explain how the modification to the critical heat flux for a target that is immersed in a thermal plume was used in the zone-of-influence (ZOI) determination.

f) Provide technical justification to demonstrate that the GFMTs approach as used to determine the ZOI of fires that involve multiple burning items (e.g., an ignition source and an intervening combustible such as a cable tray) is conservative and bounding.

g) Describe how the flame spread and fire propagation in cable trays and the corresponding heat release rate (HRR) of cables was determined, and provide technical justification for the methodology that was used. Explain how the flame spread, fire propagation and HRR estimates affect the ZOI determination and hot gas layer temperature calculations.

h) Describe how transient combustibles in an actual plant setting are characterized in terms of the three fuel package groupings in Supplement 3, "Transient Ignition Source Strength" of the GFMT. Identify areas, if any, where the NUREG/CR-6850 transient combustible HRR characterization (probability distribution and test data) may not encompass typical plant configurations. Finally, explain how any administrative action will be used to control the type of transient combustibles in a fire area.

Response

e) The modified critical heat flux was implemented using either a two or a three point treatment in the fire PRA. Most plant areas use the two point treatment of the modified critical heat flux. The first point corresponds to temperature conditions between ambient and 80 °C (176 °F) and represents the temperature interval in which the ZOIs, such as those documented in the “Generic Fire Modeling Treatments” report (1SPH02902.030), are applicable. The second point corresponds to temperature conditions greater than 80 °C (176 °F) and is conservatively characterized in the Fire PRA as a full-room burnout. This applies to both targets located in the thermal plume region and to targets that are located outside the thermal plume region. Several plant areas use a three point treatment for greater resolution on the risk characterization. The first point corresponds to temperature conditions between ambient and 80 °C (176 °F) and represents the temperature interval in which the ZOIs for thermoset cable targets are applicable. The second point corresponds to temperature conditions greater than 80 °C (176 °F) but less than 220 °C (428 °F) and represents the region where the hot gas layer can produce a heat flux up to 5.7 kW/m^2 (0.5 $Btu/s\text{-}ft^2$). The ZOIs for thermoplastic cables are applicable in this temperature range when used to identify thermoset cable targets because the total heat flux at the ZOI boundary is 11.4 kW/m^2 (1.0 $Btu/s\text{-}ft^2$), the generic threshold for thermoset cables per

NUREG/CR-6850. The third point corresponds to temperature conditions greater than 220 °C (428 °F) and is conservatively characterized in the Fire PRA as a full-room burnout. This applies to both targets located in the thermal plume region and to targets that are located outside the thermal plume region.

f) The GFMT report (1SPH02902.030, Rev. 0) provides tabulated ZOI information for ignition sources that do not involve secondary combustible materials such as cable trays or multiple ignition sources. Although the original GFMT did not explicitly consider secondary combustible materials, the ZOI developed for electrical panel ignition sources includes a conservative lower ZOI dimension that would typically exceed the ZOI dimension during the early fire stages for scenarios that involved a relatively small number of cable trays. In addition, the vertical ZOI dimension is extended to the ceiling when secondary combustibles are located in the ignition source ZOI. However, there are situations where the lower ZOI dimension would not bound the ZOI dimension if secondary combustibles were explicitly included. In addition, the ZOI dimensions for transient ignition sources would typically be non-conservative if secondary combustibles are involved. In lieu of demonstrating which scenarios are conservative relative to current NUREG guidance and which require further analysis, new ZOI tables have been developed that are applicable to ignition source – cable tray configurations at ANO-2. These ZOI tables are documented in PRA-A2-05-017, Rev 0 (see Tables 5-11 through 5-33). Supplemental plant walkdowns for secondary combustibles have been performed and documented in PRA-A2-05-016, Rev. 0. Because the method for determining the heat release rate development documented in PRA-A2-05-017, Rev 0, is consistent with applicable NUREG guidance, the approach is considered conservative and bounding.

g) Fire spread and fire propagation in cable trays is considered at ANO-2 for fire scenarios in which the ignition source fire propagates into one or more cable trays. Supplement 2 of the GFMT report (PRA-ES-05-007, Rev. 0) provides tables that document the time to reach threshold hot gas layer (HGL) temperatures for electrical panel ignition sources that ignite two adjacent 0.61 m (24 in) wide cable trays. The cable trays ignite at a plane section through the cable trays five minutes after the ignition source ignites and propagate fire laterally in two directions in a manner consistent with the NUREG/CR-6850, Appendix R, guidance for thermoplastic cables. The configuration is considered to be an average representation of an ignition source – cable tray configuration and consequently may be overly conservative in some situations and non-conservative in other situations when compared against the FLASH-CAT methodology provided in NUREG/CR-7010, Volume 1. The GFMT report (1SPH02902.030, Rev. 0) provides tabulated ZOI and HGL information for ignition sources that do not involve secondary combustible materials such as cable trays or multiple ignition sources. No consideration is provided for the additional heat release rate on the ZOI and HGL temperatures in this report; however, the general practice is to increase the vertical ZOI dimension to the ceiling when secondary combustibles are in the ZOI of the ignition source. This practice, coupled with the conservative method for which the ZOIs are developed, is considered conservative in some situations and non-conservative in other situations.

In lieu of demonstrating which scenarios are conservative relative to NUREG guidance and which require further analysis, new ZOI and HGL tables have been developed that are applicable to ignition source – cable tray configurations at ANO-2 that are derived using guidance provided in NUREG/CR-6850, Supplement 1, and NUREG/CR-7010, Volume 1. The ZOI is a function of both the heat release rate of all burning objects and the physical

spread of the fire along the cable trays. The HGL temperatures are directly affected by the total heat release rate of all burning objects. The new ZOI HGL tables are used to characterize the target sets where secondary combustibles (cable trays) are ignited by an ignition source and replace those provided in Supplement 2 to the GFMT report (PRA-ES-05-007, Rev. 0). The new ZOI and HGL tables are documented in PRA-A2-05-017, Rev. 0, and PRA-A2-05-018, Rev. 0. Because the method for determining the heat release rate development documented in PRA-A2-05-017, Rev. 0, and PRA-A2-05-018, Rev. 0, is consistent with applicable NUREG guidance, the approach is considered conservative and bounding. Supplemental plant walkdowns have been conducted to incorporate the new ZOI dimensions and are documented in PRA-A2-05-016, Rev. 0, as described in the response to Fire Modeling RAI 01(f).

h) The transient fuel packages are assumed to be miscellaneous materials (trash configurations) that do not contain acetone or other combustible liquids. This corresponds to the Group 3 and Group 4 transient fuel packages described in Supplement 3 of the "Generic Fire Modeling Treatments" report (PRA-ES-05-006, Rev. 0). The 98th percentile transient fuel packages are considered a special case of the Group 3 and Group 4 transient fuel packages with a specific heat release rate per unit area as described in the Supplement 3 of the "Generic Fire Modeling Treatments" report (PRA-ES-05-006, Rev. 0).

The transient fire heat release rate conditional probability distribution specified in NUREG/CR-6850, with a 317 kW (300 Btu/s) 98th percentile peak heat release rate fire, is considered to be generically applicable to nuclear power plants. ANO-2 does not differ in any significant manner with respect to its transient combustible controls to warrant a significant increase or decrease in the applicable heat release rate profile or heat release rate conditional probability distribution as specified in NUREG/CR-6850. However, for areas that have been designated as "no transient combustible areas," to address the potential for violation of these controls, a 69 kW (65 Btu/s) 98th percentile peak heat release rate fire is applied. This heat release rate is considered appropriate given the unlikely event that transients are stored in these areas contrary to the controls imposed. The 69 kW (65 Btu/s) peak heat release rate was defined based on the heat release rate specified in NUREG/CR-6850 for a motor fire given that the most likely transient fire in a zone with limited transients would be associated with temporary cabling since this configuration would provide both the ignition source (energized temporary cabling) and combustible (cable insulation). The motor configuration would resemble such a transient fire.

The control of combustibles will be ensured under procedure EN-DC-161, "Control of Combustibles," which limits the accumulation and composition of materials using a graded approach (Level 1 [highest risk] through Level 4 [lowest risk]). The procedure provides the framework for the introduction of combustibles into each hazard level area and the required conditions that apply when combustibles are introduced. Combustibles that do not meet the specified requirements for each hazard level require Transient Combustible Analysis (TCA) to be performed. High hazard areas (Level 1) require a TCA when any transient combustible material is introduced, whereas lower hazard areas require a TCA only when the exempt quantity is exceeded. The use of the combustible control procedure will limit the combustible configurations in high hazard areas to configurations that are bound by the analysis provided in Supplement 3 of the "Generic Fire Modeling Treatments" report (PRA-ES-05-006, Rev. 0) or, where impractical, to provide for the necessary compensatory measures via the TCA.

It is noted that there is one case considered in the MCR abandonment calculation (CALC-ANO2-FP-09-0013, Rev. 0) in which a transient fuel package fire scenario is characterized using a heat release rate profile that is more adverse than the standard NUREG/CR-6850, Appendix E, Case 8, transient fuel package fire scenario. Specifically, an office type fuel arrangement is postulated and characterized using a heat release rate profile applicable to such fuel packages. This configuration is unique to the MCR area among risk significant plant areas.

Fire Modeling RAI 01 *(continued)*

Specifically regarding the evaluation of development and timing of hot gas layer conditions:

i) Please explain why the heat release rate per unit area and flame spread rate values for thermoplastic cables were used in the FLASH-CAT cable tray fire propagation calculations.

j) Explain why the modification to the smoke concentration in the CR abandonment time analysis was not applied in the CFAST calculations of smoke detector response timing in Fire Zone 2098-C.

Response

i) The heat release rate per unit area and flame spread rate values for thermoplastic cables are assumed in the FLASH-CAT calculation documented in PRA-A2-05-011, Rev. 0, to provide a conservative margin in the results. The cables at ANO-2 are considered to be thermoset, which have a lower generic heat release rate per unit area and flame spread rate than thermoplastic cables per NUREG/CR-7010, Volume 1.

j) The smoke concentration values were not modified in the smoke detector response timing calculation provided in PRA-A2-05-011, Rev. 0, because the values have a significant conservative bias per NUREG-1934 and are thus expected to provide a conservative result. The original MCR abandonment calculation (CALC-ANO2-FP-09-00013, Rev. 0) included a factor to incorporate the uncertainty insights directly into the baseline cases. The revised MCR abandonment calculation removes the uncertainty coupling from the baseline fire scenarios and treats uncertainty separately in Section A2.3 of Attachment 2 in CALC-ANO2-FP-09-00013, Rev. 1 (see Fire Modeling RAI 01(d) response). The smoke detector response timing and the MCR abandonment calculation methods are now aligned.

Fire Modeling RAI 01 *(continued)*

Regarding the acceptability of the PSA approach, methods, and data in general:

k) Please address how it was assured that non-cable intervening combustibles were not missed in areas of the plant. Provide information on how intervening combustibles were identified and accounted for in the fire modeling analyses and the FREs.

l) Explain why wall and corner effects were only considered for transient ignition sources, and not for fixed ignition sources.

m) It appears from Table 4-3 in the LAR that there are 59 fire zones where some credit is taken in the Fire PRA for detection or suppression. Explain the process for determining which targets are damaged before suppression occurs.

n) LAR Table 4-3 indicates that selected fire zones have "partial" detection or suppression. Explain what "partial" means in this context, and whether partial coverage was credited.

Response

k) The walkdowns performed for the response to Fire Modeling RAIs 01(f) and 01(g) also included a review of the location of exposed non-cable combustibles identified in the Fire Hazards Analysis. There were isolated locations where non-cable combustibles were noted. The combustibles in these areas meet the current licensing basis and do not pose a current issue. Changes to the current program may be required to ensure these types of combustibles are appropriately controlled to support transition to NFPA 805. This will be evaluated as part of Item S2-7 in Table S-2 of the LAR.

l) The walkdowns performed to support the response to Fire Modeling RAIs 01(f) and 01(g) also reviewed and updated the scenarios for fixed ignition source scenarios within 0.61 m (2 ft) of a wall or corner. See PRA-A2-05-017 for ZOIs applicable to fixed ignition sources not near a wall/corner as well as the applicable ZOIs for those ignitions sources located within two feet of a wall/corner.

m) Credit is taken for suppression and detection to prevent HGL formation in the HGL / Multi-Compartment Analysis (MCA) evaluation. Availability of detection systems in the zone supports the use of FAQ 08-0050 non-suppression probabilities. A lack of a detection system requires reduction of the time for non-suppression by a 15-minute period to account for the delayed detection. The use of the 15-minute time is based on NRC Significance Determination Process (SDP) guidance accounting for detection by Operators due to spurious indications and/or by plant personnel.

Suppression and detection systems credited are associated with smoke/heat actuated detection systems. Suppression systems are credited to suppress a fire prior to HGL formation in support of the MCA. Suppression actuation is assumed to occur prior to a HGL temperature of 329 °C (thermoset cable damage temperature). This is a conservative assumption since the systems would be expected to actuate long before the HGL reaches this temperature. A specific fire model was developed for the credit of the fire detection system in Fire Zone 2098-C and the suppression system in Fire Zone 2109-U (PRA-A2-05-011, Rev. 0).

n) Partial detection/suppression indicates that the suppression system does not provide coverage throughout the associated fire zone. Partial coverage detection or suppression systems were not credited in the Fire PRA, except in Fire Zone 2109-U, where a detailed fire model was produced relative to the ignition sources and suppression systems (see PRA-A2-05-011, Rev. 0, Section 7.4.8).

Fire Modeling RAI 04

NFPA-805, Section 2.7.3.3, "Limitations of Use," states: "Acceptable engineering methods and numerical models shall only be used for applications to the extent these methods have been subject to verification and validation. These engineering methods shall only be applied within the scope, limitations, and assumptions prescribed for that method."

LAR Section 4.7.3, "Compliance with Quality Requirements in Section 2.7.3 of NFPA-805," states that "Engineering methods and numerical models used in support of compliance with 10 CFR 50.48(c) are used and were used appropriately as required by Section 2.7.3.3 of NFPA-805."

Regarding the limitations of use:

Please identify uses, if any, of the GFMTs (including the supplements), and CFAST outside the limits of applicability of the method and justify how the use of these fire modeling approaches were appropriate.

Response

There are two broad categories of limitations that are applicable to the GFMT approach. These include limitations associated with the implementation of the ZOI and limitations associated with the CFAST fire modeling of the HGL conditions. In addition, limitations apply to the CFAST fire modeling conducted in support of the MCR abandonment calculation (CALC-ANO2-FP-09-00013, Rev. 0 [original] and CALC-ANO2-FP-09-00013, Rev. 1 [revised]).

1. Generic Fire Modeling Treatments Approach (ZOI)

   The GFMT approach as documented in Report 1SPH02902.030, Rev. 0, and PRA-ES-05-006, Rev. 0, are intended to provide conservative ZOI dimensions for various types of ignition sources when used within the stated limitations. There are five basic limitations that should be considered when applying the original GFMT ZOIs. The five limitations represent conditions or configurations for which the GFMT ZOI data may potentially be non-conservative if applied outside the particular limitation:

   - The application of the generic ZOI data in compartments in which the HGL temperature exceeds 80 °C (176 °F)
   - The application of the generic ZOI data to fire scenarios in wall and corner configurations
   - The application of the generic ZOI data for panel ignition sources with panels having plan dimensions greater than 0.91 X 0.61 X 2.13 m (3 X 2 X 7 ft)
   - The application of the generic ZOI data to scenarios that result in flame impingement to the ceiling
   - The application of the generic HGL data to configurations in which secondary combustibles (cable trays) are ignited

Supplement 2 of the GFMT report (PRA-ES-05-007, Rev. 0) was developed to address a number of these limitations under various circumstances that arise at ANO-2. In addition, several method enhancements have been developed to address specific configurations or conditions that have been encountered when applying the GFMT in the field, including the consideration of combination ignition source - secondary combustibles fire scenarios (PRA-A2-05-017, Rev. 0; PRA-A2-05-011, Rev. 0; and PRA-A2-05-018, Rev. 0).

ZOIs in Elevated Temperature Enclosures

In most situations, ZOIs are not used above 80 °C (176 °F) to determine target failures, which effectively transitions a scenario to a full room burnout. In situations where additional resolution is needed to better quantify the risk, an extended ZOI dimension is used. The extended ZOI is based on the ZOI dimensions for thermoplastic cables and is applicable in environments where the HGL temperature radiates a heat flux equal to 5.7 kW/m^2 (0.5 Btu/s-ft^2). The total heat flux to a target located on the ZOI boundary under these conditions is 11.4 kW/m^2 (1.0 Btu/s-ft^2), the NUREG/CR-6850 steady-state threshold value for thermoset cables. The applicable limit for the expanded ZOI is 220 °C (428 °F).

ZOIs in Wall and Corner Locations

The application of the generic ZOI data to fires postulated in wall and corner configurations exceeds the original limitations of the GFMT report (Report 1SPH02902.030, Rev. 0). However, the ZOI dimensions for ignition sources in wall and corner configurations are provided in PRA-ES-05-006, Rev. 0, for transient fire scenarios and PRA-A2-05-017, Rev. 0, for electrical panel fire scenarios.

Wall and corner effects are assessed in PRA-ES-05-006, Rev. 0, for transient fire scenarios and PRA-A2-05-017, Rev. 0, using a location factor or 'Image' method approach as described in NIST-GCR-90-580. The 'Image' method is a simple means of incorporating wall and corner effects by taking advantage of the proportionality between the fire perimeter and the plume air entrainment by changing the fire area. ZOI dimensions and HGL timing provided in Report 1SPH02902.030, Rev. 0, for open locations may be used to estimate the ZOI and HGL timing for wall and corner locations identified by selecting the data for a fire size that is two or four times the actual fire size.

The Fire PRA currently addresses transient fuel packages in wall and corner configurations using the ZOI data provided in PRA-ES-05-006, Rev. 0, and the HGL tables provided in 1SPH02902.030, Rev. 0, adjusted for the particular location. The location for fixed ignition sources such as electrical panels is assumed to be open given that most panel vents are orientated away from wall boundaries. Walkdowns were performed to identify fixed ignition source fire scenarios that should be treated using wall and corner location factors. The updated fire scenario results will be provided in the update to Attachment W of the original license amendment request (LAR) (Reference 1) when all Fire PRA revisions are complete.

ZOIs for Large Dimension Electrical Panels

The original GFMT report and Supplement 2 of the GFMT report ZOI data was derived for panels having plan dimensions up to 0.91 x 0.6 m (3 x 2 ft) and a height up to 2.13 m (7 ft). The dimensions primarily affect the extent of the horizontal component of the ZOI that is below the top of the panel. This ZOI component is calculated from an energy balance at

the panel surface, and the target exposure mechanism is a heated radiating vertical plane. Consequently, changes in the panel dimensions affect the dimensions of the radiating plane, which in turn affects the geometry configuration factor between the target and the radiating plane. The lower horizontal ZOI dimension is the limiting horizontal ZOI dimension and is used in the Fire PRA as the basis for determining the affected target set.

An approximate upper limit for the ZOI dimensions based on a 0.91 x 0.61 x 2.13 m (3 x 2 x 7 ft) tall panel may be estimated by comparing against a limiting open panel configuration. In this case, the maximum heat transferred across one boundary would be given through the definition of the emissive power and a radiation area as follows:

$$\dot{Q}_{b,max} = A_b E \qquad \text{(FM 04-1)}$$

where $\dot{Q}_{b,max}$ is the maximum heat that can be transferred across a vertical boundary of an electrical panel (kW [Btu/s]), A_b is the area of the boundary (m^2 [ft^2]), and E is the flame emissive power (kW/m^2 [Btu/s-ft^2]). Assuming the maximum average flame emissive power over the panel boundary is 120 kW/m^2 (10.6 Btu/s-ft^2) based on Section 3-10 of the *SFPE Handbook of Fire Protection Engineering*, 4th Edition and data provided in *Combustion and Flame*, No. 139, pp. 263-277, the maximum heat that could be transferred across a vertical boundary via thermal radiation is about 235 kW (223 Btu/s) if the heat transferred across an open boundary is considered to be an upper limit on the boundary heat losses in any one direction. To link this heat loss to the postulated fire size, the radiant fraction is used, which is reasonably approximated as 0.3 for enclosure fires per Section 3-8 of the *SFPE Handbook of Fire Protection Engineering*, 4th Edition. Dividing the maximum boundary heat loss of 235 kW (223 Btu/s) by the radiant fraction (0.3) results in the largest fire size for which the lateral ZOI dimensions would be conservative, or 783 kW (742 Btu/s). This value exceeds the severe fire heat release rate used to characterize both the multiple bundle (717 kW [680 Btu/s] based on the Bin 8 heat release rate) and single bundle (211 kW [200 Btu/s]) electrical panels. This result is based on a radiant fraction of 0.3; if a value at the upper end of the often cited range 0.3 – 0.4 is assumed per Section 3-8 of the *SFPE Handbook of Fire Protection Engineering*, 4th Edition, the largest fire size for which the lateral ZOI dimensions would be conservative, or 588 kW (557 Btu/s). However, this would be based on all heat losses being directed toward the target. The internal temperature during a fully developed enclosure fire would be greater than 600 °C (1,112 °F), which suggest the heat losses from all boundaries, except the open boundary, would be on the order of 110 kW (104 Btu/s). This means that the maximum total energy that could radiate toward the target via thermal radiation would be about 600 kW (569 Btu/s) x 0.4 or 240 kW (227 Btu/s). This is comparable to the maximum boundary heat loss via thermal radiation (235 kW [223 Btu/s]), which indicates the conclusion applies over a wider range of radiant fractions when the additional boundary heat losses are included. There are no known applications of the panel fire ZOI dimensions to panels that have a heat release rate greater than 783 kW (742 Btu/s) in an open location and a plan size that exceeds 0.91 x 0.61 m (3 x 2 ft) within the Fire PRA. The limiting fire size (and plan dimension for the panels) for wall and corner locations is increased by a factor of two and four due to the symmetry planes assumed in the 'Image' method. This suggests that the panel size constraint is met for electrical panel ignition source fire scenarios. A review of the fixed ignition source (panel) heat release rates was performed as part of the Fire PRA updates and it was confirmed that there are no panels that exceed the limitation either by heat release rate or by dimension.

Flame Height Limitation for ZOIs

The original GFMT report limits the application of the ZOIs to situations in which the flames remain lower than the ceiling height. Subsequent analysis presented in PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev. 0, indicates that the ZOIs remain conservative provided the ceiling jet temperature at the ZOI boundary remains less severe than the threshold damage temperature for the cable target. The minimum ceiling height above the fire base is listed in PRA-ES-05-006, Rev. 0, for transient ignition sources and in PRA-A2-05-017, Rev. 0, for transient and fixed ignition sources that involve secondary combustibles. The results indicate that a ceiling height of 0.3 – 1.5 m (1 – 5 ft) above the fire base, depending on ignition source and cable tray configuration, is sufficient to meet the ceiling jet condition whether or not flame impingement occurs.

There are no known applications that fall below this range listed in PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev. 0.

ZOIs and HGL Temperatures for Scenarios with Secondary Combustibles

The ZOI and hot gas layer data provided in the original GFMT report postulates a single ignition source fire without secondary combustibles and is thus applicable to configurations that do not involve secondary combustibles, such as cable tray stacks. Supplement 2 to the GFMT report provides HGL data for a single cable tray configuration having the following characteristics:

- Total cross-sectional length of 0.9 m (3 ft) as represented by two 0.45 m (18 in) wide cable trays placed side-by-side that release heat from the top and bottom or two 0.9 m (36 in) wide trays that release heat from the top
- Heat release rate per unit area of 225 kW/m^2 (19.8 Btu/s-ft^2)
- Flame propagation rates of 0.3 mm/s (0.012 in/s) for thermoset/IEEE-383 qualified cables and 0.9 mm/s (0.035 in/s) for thermoplastic/non-IEEE-383 qualified cables
- Fire propagation in two directions
- Fire ignition at a single vertical plane located above the ignition source
- Cable tray(s) having a base height 0.3 m (1 ft) above the base of the ignition source fire
- Heat release rate per unit area reaches maximum value at the ignition time for any fixed location on the cable trays
- Ignition of the cables at five minutes after the ignition source fire starts

The HGL results are considered to be conservative when applied to configurations that meet the aforementioned constraints largely because the heat release rate per unit area is not linearly ramped over a timescale equal to one-sixth the fire duration as suggested in NUREG/CR-7010, Volume 1. Detailed HGL tables for bounding ignition source – cable tray configurations are provided in PRA-A2-05-011, Rev. 0. The heat release rates for the cable trays are determined using the guidance provided in NUREG/CR-6850 and NUREG/CR-7010, Volume 1, including the heat release rate per unit area, the flame spread rate, and the vertical propagation rate. This data is used for determining the HGL

timing associated with specific ignition source fire scenarios in multiple ANO-2 fire zones. Finally, as part of the response to Fire Modeling RAIs 01(f) and 01(g), additional HGL tables and ZOI tables have been developed for fixed and transient ignition sources that involve one through eight cable trays arranged within a single cable tray stack. This data is documented in reports PRA-A2-05-017, Rev. 0, and PRA-A2-05-018, Rev. 0. Fire scenarios that involve cable trays will be characterized in the updated Fire PRA using the ZOI and HGL data provided in Reports PRA-A2-05-017, Rev. 0, PRA-A2-05-018, Rev. 0, and PRA-A2-05-011, Rev. 0. These reports will replace the method provided in PRA-ES-05-007, Rev. 0, in the updated Fire PRA. The updated fire scenario results will be provided in the update to Attachment W of the original LAR (Reference 1) when all Fire PRA revisions are complete.

2. GFMT Approach (HGL Calculations)

The GFMT approach involves two types of CFAST calculations:

- Generic enclosures that minimize the heat losses to the boundaries (reports 1SPH02902.030, Rev. 0, and PRA-A2-05-018, Rev. 0)
- Specific enclosures that use the actual enclosure height and minimize the heat losses through the wall and ceiling boundaries (PRA-A2-05-011, Rev. 0)

The key CFAST model limits that apply to the ANO-2 CFAST evaluations as identified in NIST SP 1026 and NUREG-1824, Volume 5, are as follows:

- Maximum vent size to enclosure volume ratio should not exceed 2 m^{-1} (0.61 ft^{-1})
- Maximum enclosure aspect ratio of five (length to width)

The approach adopted in both the generic and the specific enclosure analysis is to evaluate a range of ventilation fractions, from 0.001 to 10 percent of the enclosure boundary. Given that the width is set equal to the length in both the generic and specific enclosure evaluations, the maximum vent size to enclosure volume ratio is given by the following equation:

$$\frac{W + 2H}{5HW} \qquad \text{(FM 04-2)}$$

where *W* is the enclosure width or length (m [ft]), and *H* is the enclosure height. Based on the definition of the generic volume, the enclosure height is one-half the enclosure width, so that the vent size to enclosure volume ratio can only exceed 2 m^{-1} (0.61 ft^{-1}) if the ceiling height is 0.2 m or less. Because the minimum ceiling height considered is 1.4 m (4.5 ft), this condition is necessarily met. Based on Equation FM 04-2, for a vent area that is ten percent of the boundary area, the largest ceiling height that yields a vent size to enclosure volume ratio of 2 m^{-1} (0.61 ft^{-1}) is 0.3 m. All of the specific enclosures evaluated in PRA-A2-05-011, Rev. 0, have ceiling heights significantly larger than 0.3 m (1 ft); thus, this limitation is met in all ANO-2 CFAST models.

Enclosure Aspect Ratio Considerations

A final limitation of the GFMT report (1SPH02902.030, Rev. 0), Supplement 2 of the GFMT report (PRA-ES-05-007, Rev. 0), and the reports addressing HGL effects for ignition source - secondary combustible configurations (PRA-A2-05-018, Rev. 0, and PRA-A2-05-011, Rev. 0) relates to the maximum aspect ratio of an enclosure for which HGL data is applied. The HGL information is provided for enclosures having an aspect ratio up to five, per NUREG-1824, Volume 5, Section 3.2. In situations where the model is applied to enclosures having a larger aspect ratio, the behavior transitions to a channel flow typical of a corridor configuration. Localized effects in the vicinity of the fire could be more severe than the average conditions throughout the enclosure length, and thus a non-conservative result could be generated. NUREG-1934 describes a method to apply a fire model in a conservative manner under these conditions. This method involves the modification of the enclosure dimensions such that the application falls within the model limitation and the HGL temperature results are conservative. This modification is incorporated directly into the specific enclosure analysis for enclosures or enclosure models that have aspect ratios greater than five, thus the limitation does not apply to PRA-A2-05-011, Rev. 0. A review of the enclosure aspect ratios will be performed as part of the Fire PRA update, and applications in enclosures that exceed the limiting aspect ratio will be adjusted using the method provided in NUREG-1934. The updated fire scenario results will be provided in the update to Attachment W of the original LAR (Reference 1) when all Fire PRA revisions are complete.

3. Main Control Room Abandonment Calculation

The key CFAST model limits that apply to the ANO-2 MCR abandonment calculation (report 1SPH02902.030, Rev. 0) as identified in NIST SP 1026 and NUREG-1824, Volume 5 are as follows:

- Maximum vent size to enclosure volume ratio should not exceed 2 m^{-1} (0.61 ft^{-1})
- Maximum enclosure aspect ratio of five (length to width)

The maximum vent sizes considered in the MCR abandonment calculation consist of a single open door, a louver, and a damaged glass boundary. The total vent size to enclosure volume ratio for this opening combination remains much less 2 m^{-1} (0.61 ft^{-1}) and indicates this limitation is met for all CFAST evaluations.

There are four primary spaces used to evaluate fires in the MCR: the ANO-1 and ANO-2 MCR areas and the ANO-1 and ANO-2 electrical equipment areas. The approximate aspect ratio for each of these spaces is as follows (CALC-ANO2-FP-09-00013, Rev. 1):

- ANO-1 MCR area: 1.83
- ANO-2 MCR area: 1.88
- ANO-1 electrical equipment area: 1.15
- ANO-2 electrical equipment area: 1.35

These aspect ratios are less than the CFAST limit of five and indicate this limitation is met for all CFAST evaluations.

Fire Modeling RAI 06

NFPA-805, Section 2.7.3.5, "Uncertainty Analysis," states: "An uncertainty analysis shall be performed to provide reasonable assurance that the performance criteria have been met."

Section 4.7.3, "Compliance with Quality Requirements in Section 2.7.3 of NFPA-805," of the LAR states that "Uncertainty analyses were performed as required by Section 2.7.3.5 of NFPA-805 and the results were considered in the context of the application. This is of particular interest in fire modeling and fire PRA development."

Regarding the uncertainty analysis for fire modeling, please:

a) Describe how the uncertainty associated with the fire model input parameters was accounted for in the fire modeling analyses.

b) Describe how the "model" and "completeness" uncertainty was accounted for in the fire modeling analyses.

Response

a) Fire model uncertainty associated with the fire model input parameters was not explicitly accounted for in the fire PRA development at ANO-2. However, the uncertainty associated with specific fire modeling parameters is addressed through the use of a conservative and bounding analysis, and sensitivity studies are provided in the various documents that demonstrate this. There are four primary areas at ANO-2 in which fire modeling parameter uncertainty is applicable:

- The main control room (MCR) abandonment analysis (CALC-ANO2-FP-09-00013, Rev. 1);
- The hot gas layer (HGL) tabulations as contained in 1SPH2902.030, Rev. 0, PRA-A2-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0;
- The Zone of Influence (ZOI) tabulations as contained in 1SPH2902.030, Rev. 0, PRA-ES-05-006, Rev. 0; and PRA-A2-05-017, Rev. 0; and
- Detector response calculations as contained in PRA-A2-05-011, Rev. 0.

Note that HGL tables provided in PRA-ES-05-007, Rev. 0, have been replaced by the tables provided in PRA-A2-05-011, Rev. 0 and PRA-A2-05-018, Rev. 0 in the updated fire PRA (see response to RAI FM 01g).

MCR Abandonment Calculation

The updated MCR abandonment calculation CALC-ANO2-FP-09-00013, Rev. 1, is structured to provide a reasonably conservative abandonment time for a given heat release rate input over a range of potential input parameter values. The MCR abandonment calculation provides baseline cases for fifteen forced and natural ventilation combinations and effectively provides a sensitivity assessment on these parameters. Specifically, for a given fire scenario considered in the fire PRA, the shortest abandonment time among the various natural ventilation configurations is selected. In order to ensure the analysis results are conservative relative to the uncertainty in other parameters, a fire modeling sensitivity

analysis is provided in Attachment 2 to CALC-ANO2-FP-09-00013, Rev. 1. The sensitivity analysis is used to justify the selection of the input parameter values for the baseline cases using both an absolute abandonment time variation criterion (fifteen percent) and a variation in the total probability of abandonment criterion (fifteen percent). The total probability of abandonment is defined as a product of the severity factor for a particular heat release rate bin and the probability of non-suppression summed over the applicable number of heat release rate bins. A three bin summation is used in the sensitivity analysis whereas a fifteen bin summation is used when comparing the baseline fire scenarios. The sensitivity analysis demonstrates that the parameter sensitivity may be grouped as follows over the range of parameter uncertainty:

- The parameter does not significantly affect the analysis results over the potential range of values that could be assigned to the parameter (Sensitivity Group 1);
- The parameter does affect the analysis results, but the value selected for the baseline case is conservative (Sensitivity Group 2); and
- The parameter does affect the analysis results and the value selected for the baseline case is non-conservative (Sensitivity Group 3).

A significant effect is defined as a fifteen percent variation in the probability of MCR abandonment as summed over three heat release rate bins. The fifteen parameters are evaluated against baseline fire scenarios that consist of the single and multiple bundle electrical panel ignition sources and transient ignition sources. Except where door parameters and ventilation parameters are assessed, the baseline configuration involves a MCR configuration with normal heating, ventilation, and air conditioning (HVAC) conditions and with all boundary doors closed.

The parameters that fall into Sensitivity Group 1 include the assumed boundary leakage fraction, the assumed fuel heat of combustion, and several other parameters that are specific to some ignition sources or fire locations. The timing of the smoke purge transition would also fall into Sensitivity Group 1, if the timing of the transition is between 2.5 minutes and 6.5 minutes.

Parameters that fall into Sensitivity Group 2 include the assumption that the barrier performance remains intact for fires in ANO-2, the assumed burning regime for transient fires, the assumed radiant fraction, and the assumed fire base height.

One parameter falls into Sensitivity Group 3: the initial ambient temperature. In this case, it is shown that the baseline scenarios are conservative or the effect is not significant for initial ambient temperatures up to about 34 °C (93 °F). The maximum design basis temperature for the MCR is 28.9 °C (84 °F), so an initial temperature greater than 34°C (93 °F) would represent an off-normal condition. The results of this analysis should, therefore, not be used, if the postulated scenario would have an initial temperature greater than 34 °C (93 °F) in the MCR.

Based on Attachment 2 of CALC-ANO2-FP-09-00013, Rev. 1, the baseline results presented in the MCR abandonment calculation are considered conservative with respect to uncertainty in the parameter values.

Hot Gas Layer (HGL) Tabulations

The Generic Fire Modeling Treatments report (1SPH02902.030, Rev. 0), PRA-A2-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0 provide times at which the HGL in a generic enclosure will exceed specified temperature thresholds. The computations are performed using the zone computer model CFAST, Versions 6.0.10 and Version 6.1.1. The methodology for computing the HGL tables is described in detail in Section 6.3 and Appendix B of the Generic Fire Modeling Treatments report (1SPH02900.030, Rev. 0). Essentially, CFAST is used to balance energy and mass flow through openings and the time at which the HGL temperature reaches a threshold value is reported regardless of the HGL height. The primary input parameters include the fire size, the enclosure geometry, the fuel properties, the opening characteristics, the boundary material properties, and the initial ambient temperature.

The fire size is a prescribed input per NUREG/CR-6850 or is specified with a particular set of input parameters and subject to the parameter constraints (ignition source - cable tray fire scenarios). The room geometry is selected in such a way as to minimize the heat losses to the boundaries and thus varies from volume to volume. Under this assumption, the height of the enclosure necessarily varies with the volume. However, a sensitivity analysis is conducted on the room enclosure shape (Section B.4.4 of the Generic Fire Modeling Treatments report (1SPH02900.030, Rev. 0)) and it is shown that minimizing the enclosure boundary surface area provides a bounding or nearly bounding result for a given enclosure volume when the length to width aspect ratio is varied from 1:1 to 1:5 in the cases considered. As the aspect ratio increases, a significant reduction in the temperature is observed indicating that spaces that deviate from a 1:1 aspect ratio have an increasing safety margin embedded in the HGL temperature results.

The selection of the fuel properties is evaluated in Sections B.4.1 and B.4.2 of the Generic Fire Modeling Treatments report (1SPH02900.030, Rev. 0). Fuel properties are varied over a large range of potential values and the most adverse combination is selected to represent all fuels. In this case a relatively low soot yield material is used because it reduces the radiant heat losses from the HGL to the enclosure boundaries and maximizes the HGL temperature.

The opening characteristics are described in terms of a boundary fraction and are varied over a range of 0.001 – 10 percent in the baseline cases. The HGL associated with the most adverse ventilation case is selected in the fire PRA among the reported ventilation conditions for a given fire size and enclosure volume. The key input parameter that is set is the ventilation geometry (length, width, and base height) given a vent fraction.
Section B.4.5 of the Generic Fire Modeling Treatments report (1SPH02900.030, Rev. 0) provides a sensitivity analysis on the effects of various vent orientations and placements on the predicted temperature. A total of fifty-four vent configurations were examined for the baseline enclosures. It is found that the bounding case can be one of three orientations: one in which the vent width is equal to the enclosure width, located either at the ceiling or at the floor, and one in which the vent height is equal to the enclosure height. All HGL tables reported in the Generic Fire Modeling Treatments report (1SPH02900.030, Rev. 0), PRA-A2-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, are based on the most adverse HGL condition among the three vent orientations and thus represent the bounding configuration for the vent geometry.

The boundary material properties are defined as concrete having the lowest thermal diffusivity reported among available data as described in Section B.4.3 of the Generic Fire Modeling treatments report. The thermal diffusivity of the selected concrete, defined as the thermal conductivity divided by the heat capacity and density, is 5.9 x 10^{-7} m^2/s (6.3 x 10^{-6} ft^2/s) and is about thirty percent lower than the value of 8.9 x 10^{-7} m^2/s (9.6 x 10^{-6} ft^2/s) recommended in NUREG-1805. This conservatively biases the results for the boundary materials, though it is shown in Section B.4.3 of the Generic Fire modeling Treatments report (1SPH02900.030, Rev. 0) that the results are not conservative if they are applied to spaces bound with thermal insulation, lightweight concrete, or gypsum wallboard.

The initial ambient temperature is assumed to be 20 °C (68 °F) in the Generic Fire Modeling Treatments report (1SPH02920.030, Rev. 0), PRA-A2-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0. Although an ambient temperature of 20 °C (68 °F) is not a conservative and bounding assumption, the effect is readily bound by other conservative aspects of the model approach such as the enclosure geometry, ventilation effects, fuel properties, and HGL position.

Finally, a significant conservatism embedded in the CFAST model results is the specification of an adiabatic floor. Radiant heat losses from both the fire and the HGL to the floor are not credited with reducing the HGL temperature. This assumption is expected to conservatively bias the temperature predictions.

Based on the overall conservative bias associated with the CFAST model parameters (collectively), the HGL tables reported in the Generic Fire Modeling Treatments report (1SPH02900.030, Rev. 0), PRA-A2-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, are considered conservative with respect to uncertainty in the parameter values.

ZOI Calculations

The Generic Fire Modeling Treatments report (1SPH2902.030, Rev. 0), PRA-ES-05-006, and PRA-A2-05-017, Rev. 0, provide ZOI dimensions for various ignition sources and combination ignition sources – cable tray configurations for which fire PRA fire scenarios are developed. The tabulated ZOI dimensions are all based on the methodologies described in Generic Fire Modeling Treatments report (1SPH2902.030, Rev. 0), except the ZOI dimensions for the ignition source – secondary combustible configurations include the physical offset associated with both the cable tray arrangement and the fire spread in the cable trays. The ZOI dimensions essentially consist of a vertical component derived from a plume exposure correlation and one or more horizontal components, each derived from a radiant heat flux calculation.

The vertical plume calculation uses an empirical model that requires as inputs the fire size, the ambient temperature, and fire diameter. The fire size is an input parameter specified by NUREG/CR-6850. The fire diameter and ambient temperature are the primary parameters subject to uncertainty. In this case, the fire diameter in the original Generic Fire Modeling Treatments report (1SPH2902.030, Rev. 0) provides ZOI dimensions assuming a variable diameter (as characterized using the heat release rate and heat release rate per unit area). A heat release rate per unit area range between 200 kW/m^2 (17.6 $Btu/s\text{-}ft^2$) and 1,000 kW/m^2 (88.1 $Btu/s\text{-}ft^2$) is used for transient combustible materials and range up to 3,000 kW/m^2 (264 $Btu/s\text{-}ft^2$) for electronic panels. The baseline ambient temperature assumed in the original Generic Fire Modeling Treatments report (1SPH2902.030, Rev. 0)

is 20 °C (68 °F) with a maximum application limit of 80 °C (176 °F). The baseline ambient temperature selection in PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev. 0, is varied from 20 °C (68 °F) to 80 °C (176 °F) and is thus not subject to assumption or uncertainty, at least within the limits of applicability.

The maximum effect of an elevated initial ambient temperature on the ZOI dimensions for transient fuel package fires is provided in PRA-ES-05-006, Rev. 0, and in PRA-A2-05-017, Rev. 0, for various ignition source – cable tray configurations. The ZOI dimension may change by about two to five percent when the ambient temperature is 40 °C (104 °F) and ten to twenty percent if the ambient temperature is 80°C (176°F) ,based on various ignition sources and cable tray configurations evaluated in open, wall, and corner locations. This differential is expected to be readily bound by the conservatisms that are embedded in the ZOI development. These conservatisms relative to a transient fuel package fire include the use of steady-state target damage thresholds, a fire diameter that maximizes the ZOI dimension, the use of a ZOI box rather than a cone, and the selection of the most adverse result among a range of methods. PRA-A2-05-017, Rev. 0, also provides an assessment of the calculation results to uncertainty in the assumed fire diameter and it is shown that the variation is less than the ZOI resolution implemented in the field.

An additional offsetting conservative factor for the panel fires relative to an elevated ambient temperature environment is the assumed heat release rate per unit area for the electronic panel fires for the vertical ZOI dimension, which is effectively 3,000 kW/m^2 (264 $Btu/s\text{-}ft^2$). This means that the characteristic fire dimension for the 98th percentile panel fires is on the order of 0.26 – 0.48 m (0.9 – 1.6 ft). The characteristic dimension for the electronic panels as evaluated using the NUREG/CR-6850 guidance would be based on the panel top surface area and will typically be on the order of 0.6 – 1.2 m (2 – 4 ft). This indicates a significant bias is introduced by assuming the fire plan area can occupy only a fraction of the panel top. An additional conservative bias is introduced in setting the base location of the vertical ZOI dimension. Per NUREG/CR-6850, Supplement 1, the fire base height may be set 0.3 m (1 ft) below the panel top (if the panel does not have significant openings in the top). The vertical ZOI dimensions for the electronic panels reported in the Generic Fire Modeling Treatments report (1SPH2902.030, Rev. 0) use the panel top as the base height reference for the vertical ZOI dimension. This introduces a uniform 0.3 m (1 ft) bias in all vertical ZOI dimensions for the electronic panels. As such, the vertical ZOI dimension is calculated using bounding input parameters when viewed collectively.

In the case of the horizontal ZOI dimension, the maximum distance as obtained using the more severe prediction among both a solid flame model and the Point Source Model (PSM). The ZOI dimensions for the ignition source – cable tray configurations are obtained in a similar manner, but include heat flux calculations for using the total heat release rate of all heat sources and the heat flux calculations using the sum of the ignition source and cable trays contributions. The PSM requires as input the fire size and the fire radiant fraction. The fire size is a prescribed input per NUREG/CR-6850. Based on *SFPE Handbook of Fire Protection Engineering*, Section 3-10, the effective radiant fraction for conservative (but not bounding) results is 0.21. A bounding result is obtained when a safety factor of two is used. Therefore, the fire radiant factor is assumed to be 0.4. As a result, by assuming a radiant fraction of 0.4, an effectively bounding result is therefore obtained. The solid flame heat flux model requires the fire size and fire diameter as input parameters. The fire size is a prescribed input per NUREG/CR-6850. The fire diameter is

varied via the heat release rate per unit area parameter. In this case, the most adverse fire diameter is intermediate with a heat release rate per unit area of about 350 – 400 kW/m^2 (30.8 – 35.2 $Btu/s\text{-}ft^2$), depending on the specific case. The value that yields the maximum ZOI dimension is the value used in the analysis.

The electronic panel ignition source ZOIs have additional conservative margins by including an additional calculation that is more conservative than the approach suggested in NUREG/CR-6850, Supplement 1. Per NUREG/CR-6850, Supplement 1, the fire base is located 0.3 m (1 ft) below the top of the panel and is typically modeled assuming the panel boundaries do not exist (open fire). The horizontal ZOI dimensions developed in the Generic Fire Modeling Treatments report (1SPH02902.030, Rev. 0) include an upper horizontal ZOI dimension that is computed in this manner and a lower ZOI dimension that assumes internal flame impingement on the panel boundary. This flame impingement imposes a 120 kW/m^2 (10.6 $Btu/s\text{-}ft^2$) heat flux on any internal boundary that radiates outward from a single side. The lower horizontal ZOI dimension is significantly larger than the upper fire plume base horizontal dimension, typically by a factor of two (compare Tables 5-16 and 5-17 in the Generic Fire Modeling Treatments report (1SPH02902.030, Rev. 0), for example). The fire PRA selects the most adverse horizontal ZOI dimension and thus incorporates this bias directly.

Based on the overall conservative bias associated with the input parameter, both the horizontal and vertical ZOI dimensions reported in the Generic Fire Modeling Treatments report (1SPH02902.030, Rev. 0), PRA-ES-05-006, Rev. 0, and PRA-A2-05-017 are considered conservative with respect to parameter uncertainty.

Smoke Detector Calculation

An analysis of the smoke detector response and corresponding damage times is provided in PRA-A2-05-011, Rev. 0, for one fire area, Fire Zone 2098-C. The analysis uses CFAST to predict the fire generated conditions that drive the detector activation. The CFAST model is used to predict the smoke optical density, which in turn is used to predict the smoke detector activation time. The primary uncertainly parameters in this calculation are the source fire heat release rate and the smoke detector activation threshold. In the case of the fire heat release rate parameter, this input was assessed over the entire heat release rate conditional probability distribution provided in NUREG/CR-6850 for the applicable ignition source. As such, the heat release rate parameter is considered to be conservative for ignition source classes evaluated. In the case of the threshold smoke optical density for smoke detector activation, the selected value is based on performance guidelines provided by Geiman and Gottuk in the *Proceedings of the 7^th^ International Symposium of Fire Safety Science.* The selected optical density value corresponds to the smoke optical density at which ninety-one percent of installed detectors actuate and is thus reasonably bounding and conservative relative to the data.

b) Fire modeling "model" and "completeness" uncertainty was not explicitly accounted for in all fire modeling evaluations or incorporated into the fire PRA at ANO-2. However, the uncertainty associated with fire modeling "model" and "completeness" uncertainty is addressed through the use of a conservative and bounding analysis. There are four primary areas at ANO-2 in which fire modeling "model" and "completeness" uncertainty is applicable:

- The main control room (MCR) abandonment analysis (CALC-ANO2-FP-09-00013, Rev. 1);
- The hot gas layer (HGL) tabulations as contained in 1SPH2902.030, Rev. 0, PRA-A2-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0;
- The Zone of Influence (ZOI) tabulations as contained in 1SPH2902.030, Rev. 0, PRA-ES-05-006, Rev. 0; and PRA-A2-05-017, Rev. 0; and
- Detector response calculations as contained in PRA-A2-05-011, Rev. 0.

Note that hot gas layer tables provided in PRA-ES-05-007, Rev. 0, have been replaced by the tables provided in PRA-A2-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, in the updated fire PRA (see response to RAI FM 01g).

MCR Abandonment Calculation

The MCR abandonment calculation (CALC-ANO2-FP-09-00013, Rev. 1) provides an assessment of the model uncertainty in Section A2.3 of Attachment 2 using the methods described in NUREG-1934. The uncertainty is assessed for a range of heat release rate bins associated with the primary baseline fire scenario ignition sources in MCR area. Table A2-14 of CALC-ANO2-FP-09-00013, Rev. 1, shows that the maximum probability the actual abandonment time would be fifteen percent or more lower than the predicted value is less than 7.44 percent for transient and electronic panel fire scenarios in the MCR. Based on the sensitivity analysis presented in Section A2.2 of CALC-ANO2-FP-09-00013, Rev. 1, it may be concluded that the “model” and “completeness” uncertainties are bound by the conservative bias introduced by the parameter selection.

Hot Gas Layer Tabulations

The hot gas layer tables are computed using the zone computer model CFAST, Versions 6.0.10 and 6.1.1 in the Generic Fire Modeling Treatments report (1SPH2902.030, Rev. 0) and in the detailed evaluations of secondary combustible configurations (PRA-A2-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0). As described in the response to RAI FM-06a, there are a significant number of parameters that are conservatively biased in the model, including the fuel properties, the combustion properties, the boundary properties, the adiabatic floor surface, and the vent configuration. In addition, for a given CFAST geometry, the fire PRA selects the most adverse scenario among a ventilation range between 0.001 and 10 percent of the enclosure boundary area. The approximate effect of each of these parameters (except for the adiabatic floor surface) on the temperature results are provided in Appendix B of the Generic Fire Modeling Treatments report (1SPH02902.030, Rev. 0). For example, Figures B4-7a through B4-7c and B4-8a through B4-8b in the Generic Fire Modeling Treatments report (1SPH02902.030, Rev. 0) demonstrate that the effect of changing the thermal diffusivity of the boundary materials on the steady state temperature is roughly proportional to the change in the thermal diffusivity at least when centered on a value of 5.9×10^{-7} m^2/s (6.3×10^{-6} ft^2/s). Given that this value is about thirty percent lower than the thermal diffusivity recommended in NUREG-1805 for normal weight concrete, a comparable test case would have a temperature reduction of about 93 °C (167 °F). This sensitivity alone is comparable to the temperature change necessary to reduce the “model” and “completeness” uncertainty to less than two percent as determined using the methods described in NUREG-1934 (i.e., the probability of

exceeding the critical value due to model uncertainty is less than two percent when the hot gas layer temperature is about 93 °C (167 °F) lower than the critical value). When all conservatively biased input parameters are considered together, it is expected that the collective effect on the predicted temperature will result in a low probability of exceeding a threshold value at a tabulated time.

Consequently, it is concluded that fire model “model” uncertainty would not contribute significantly to the risk uncertainty because it is sufficiently bound by the conservatisms in the CFAST hot gas layer analyses.

ZOI Calculations

The ZOI computations provided in the Generic Fire Modeling Treatments report (1SPH02902.030, Rev. 0) and in the analysis of secondary combustible configurations (PRA-A2-05-018, Rev. 0) rely on a plume centerline temperature, an open source fire radiant heat flux computation, and a radiant heat flux computation from a heated panel or burning array of cables. The plume centerline temperature computation is shown in NUREG-1934 and NUREG-1824, Volume 3, to have a non-conservative bias and a relatively large standard deviation. However, the application considered did not explicitly account for the hot gas layer temperature changes, which are the expected source of the bias and variation. Similar plume correlations used by CFAST and MAGIC show a conservative bias and smaller variation. The application of the plume correlations is limited in the Generic Fire Modeling Treatments report (1SPH02902.030, Rev. 0) and PRA-A2-05-017, Rev. 0, to 80 °C (176 °F) or less through the use of the modified critical heat flux, which is intended to adapt the models for elevated internal temperatures. Further, as discussed in the response to RAI FM-06a, the vertical plume ZOI dimension may have as much as a 0.3 m (1 ft) conservative bias embedded based on the assumed diameters and the base elevations relative to NUREG/CR-6850 and NUREG/CR-6850, Supplement 1, guidelines.

The horizontal ZOI dimensions are computed using a radiant heat flux model with the radiant fraction set to about two times the value recommended in the *SFPE Handbook of Fire Protection Engineering*, Section 3-10. Effectively, the radiant heat flux has a bias of two explicitly embedded in the calculation. The probability that the heat flux at a fixed location would exceed the IEEE-383 qualified/thermoset cable limit of 11.4 kW/m^2 (1.0 Btu/s-ft^2) given a prediction of 5.70 kW/m^2 (0.50 Btu/s-ft^2) (i.e., removed conservative bias) may be computed using the methods described in NUREG-1934 with the bias and normalized variance for the radiant heat flux models, which are 2.02 and 0.59. The resulting probability is nearly zero. In the case of the electronic panel fires, an additional margin is provided through the use of a conservative model beyond that required in NUREG/CR-6850 and NUREG/CR-6850, Supplement 1, for portions of the ZOI below the panel. Because fire PRA uses the most adverse horizontal ZOI dimension above or below the panel, this additional model introduces a second conservative factor.

Consequently, it is concluded that fire model “model” and “completeness” uncertainty either would not contribute to the risk uncertainty or are bound by the conservatisms in the analysis, depending on the ZOI dimension considered.

Detector Response Analysis

An analysis of the smoke detector response and corresponding damage times is provided in PRA-A2-05-011, Rev. 0, for one fire area, Fire Zone 2098-C. The analysis uses CFAST to predict the fire generated conditions that drive the detector activation. Here, the model predicted smoke optical density is used directly to predict the smoke detector response time against the industry reported smoke detector performance. While this analysis does not provide a model uncertainty analysis, a number of conservatively biased assumptions are discussed within the original report. These include the use of the CFAST averaged upper layer smoke optical density instead of a smoke plume or ceiling jet. This approach is considered to be bounding conservative because most smoke detectors have been observed to activate according to the arrival of plume or ceiling jet gases, which are typically very optically dense smoke. The CFAST averaged upper layer smoke optical density in comparison is considerably diluted and requires additional time to reach the detection threshold. The detector performance guideline recommended by Geiman and Gottuk in the *Proceedings of the 7th International Symposium of Fire Safety Science* is sufficient to ensure that 91% of ionization smoke detectors would alarm prior to achieving that level of obscuration. This approach is also considered to be conservative because there is a 91% chance that the installed smoke detectors have a lower threshold for detection and could provide detection sooner than predicted.

However, the reported CFAST model bias for smoke concentration is 2.65 per Table 4-1 in NUREG-1934, which implies that the model over-predicts the smoke optical density. This can result in a non-conservative model uncertainty in the prediction of smoke detection. A simple means of assessing the probability that, given a prediction, the value will be different, is provided in NUREG-1934. In the case of the smoke detector response timing in Fire Zone 2098-C calculation, the performance is defined by the smoke optical density. Thus, the problem may be reduced to determining the probability that, given a predicted activation time, the actual activation time would be greater than the time to damage the cables. This probability may be determined from the following equation:

$$P(x > x_c) = \frac{1}{2}\mathrm{erfc}\left(\frac{x_c - \mu}{\sigma\sqrt{2}}\right) \qquad \text{FM06b-1}$$

Where P is the probability, x is a parameter value, x_c is a threshold parameter value, μ means 'true' predicted value of the parameter, and σ is the standard deviation of the model prediction for the parameter of interest. The mean value is determined from the model bias as follows:

$$\mu = M / \delta \qquad \text{FM06b–2}$$

where M is the model prediction and δ is the model bias. The standard deviation is computed from the normalized standard deviation as follows:

$$\sigma = \tilde{\sigma}_M(M / \delta) \qquad \text{FM06b–3}$$

Where $\sigma = \tilde{\sigma}_M$ is the normalized standard deviation.

The model bias and normalized standard deviation for the CFAST, Version 6.1.1, model are as follows, per NUREG-1934:

- Visibility (model bias): 2.65
- Visibility (normalized standard deviation): 0.63

To assess the model uncertainty, the probability that the model prediction would be non-conservative relative to the expected failure time of exposed cable targets is determined. Following this approach, the maximum probability the actual detector activation time would be greater than the predicted value for target damage is about 13 percent on average for electrical cabinet fires with thermoset cable properties reported in PRA-A2-05-011, Rev. 0. Results of this analysis are provided in Table FM06b-1. Consequently, it is concluded that fire model "model" and "completeness" uncertainty either would not contribute substantially to the risk uncertainty or they are bound by the conservatisms in the analysis.

Table FM06b-1 – Detector Activation Time Uncertainty for Fire Zone 2098-C.

Heat Release Rate Bin	Predicted Detector Activation Time (min)	Predicted Time for Cable Damage (min)	Optical Density at Cable Damage Time (1/m [1/ft])	Probability of Cable Failure Prior to Detection (-)
1	4.9	>6	0.232 (0.071)	0.328
2	3.0	3.8	0.254 (0.077)	0.267
3	2.4	3.2	0.256 (0.078)	0.262
4	2.1	2.8	0.265 (0.081)	0.237
5	1.9	2.6	0.288 (0.088)	0.176
6	1.8	2.5	0.295 (0.090)	0.159
7	1.7	2.3	0.291 (0.089)	0.169
8	1.6	2.3	0.329 (0.100)	0.080
9	1.5	2.2	0.310 (0.095)	0.123
10	1.4	2.1	0.341 (0.104)	0.056
11	1.4	2.1	0.372 (0.113)	0.002
12	1.3	2.0	0.336 (0.102)	0.066
13	1.3	2.0	0.360 (0.110)	0.019
14	1.2	1.9	0.384 (0.117)	0.021
15	1.1	1.9	0.373 (0.114)	0.003
			Average:	0.1312

Probabilistic Risk Assessment (PRA)

Note: PRA RAIs 01 (except 01d and 01gi), 02, 03, 04, 05, 06, 07, 09, 10, 11, 12, 13, 15, 18, and 19 responses were submitted in Entergy's 60-day response letter (Reference 3). PRA RAIs 01d and 08 were submitted in Entergy's 90-day response letter (Reference 4). Several of the 60-day and 90-day responses required PRA results to be submitted

following update of the fire model. These results (PRA RAIs 03, 05, 06, 09, and 10) will be provided in a revised Attachment W following model update or in conjunction with the response to future RAIs, if any.

PRA RAI 01 – Fire PRA Facts and Observations (F&Os)

Section 2.4.3.3 of NFPA-805 states that the probabilistic safety assessment (PSA is also referred to as PRA) approach, methods, and data shall be acceptable to the authority having jurisdiction, which is the NRC. RG 1.205 identifies NUREG/CR-6850 as documenting a methodology for conducting a fire PRA and endorses, with exceptions and clarifications, NEI 04-02, Revision 2, as providing methods acceptable to the staff for adopting a fire protection program consistent with NFPA-805. RG 1.200, "An Approach For Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," 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 for evaluations that could influence the regulatory decision. The primary results of a peer review are the F&Os recorded by the peer review and the subsequent resolution of these F&Os.

Please clarify the following dispositions to fire F&Os and Supporting Requirement (SR) assessment identified in Attachment V of the license amendment request that have the potential to impact the fire PRA results and do not appear to be fully resolved:

g) FSS-E2-01 (Finding, Not Met at CC-I/II/III)

The disposition to this F&O refers to a method submitted to the Electric Power Research Institute (EPRI) Fire PRA Methods Panel regarding the conditional probability of fire propagation from electrical cabinets that was rejected in a letter from NRC staff (letter from Joseph Giitter of NRC to Biff Bradley of NEI dated June 21, 2012, see ADAMS Accession No. ML12171A583). Section V.2.2 of the LAR cites a sensitivity study performed to remove credit for the electrical panel factors associated with this approach and incorporated the results of new fire modeling. In light of this, please provide:

i. The results of the sensitivity study cited in Section V.2.2 of the LAR, on fire CDF, LERF, ΔCDF, and ΔLERF.

Response

As described in the response to RAI PRA-06 in Entergy letter dated November 7, 2013 (Reference 3), the sensitivity study cited in Section V.2.2 of the LAR determined the fire CDF, LERF, ΔCDF, and ΔLERF after removal of the unapproved methods (UAMs) and a few other changes, including use of NUREG/CR-6850, Supplement 1, ignition frequencies.
Table 1 (below) provides the results of the sensitivity study cited in LAR Section V.2.2. The sensitivity study included the use of the NUREG/CR-6850, Supplement 1, ignition frequencies as well as a sensitivity study that includes results using the original NUREG/CR-6850 ignition frequencies (i.e., without use of the Supplement 1 ignition frequencies). These values do not reflect model revisions being performed to address NRC RAIs.

Table 1

Results of the Sensitivity Study Cited in LAR Section V.2.2

	CDF	ΔCDF	LERF	ΔLERF
Sensitivity study cited in LAR Section V.2.2 with NUREG/CR-6850, Supplement 1, ignition frequencies	4.76E-05	-2.62E-04	9.90E-07	-9.04E-06
Sensitivity study cited in LAR Section V.2.2 without NUREG/CR-6850, Supplement 1, ignition frequencies	7.19E-05	-4.15E-04	1.52E-06	-1.43E-05

PRA RAI 14 – Sensitive Electronics

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 fire PRA and endorses, with exceptions and clarifications, NEI 04-02, Revision 2, as providing methods acceptable to the staff for adopting a fire protection program consistent with NFPA-805. In letter dated July 12, 2006, to NEI (ADAMS Accession No. ML061660105), the NRC established the ongoing FAQ process where official agency positions regarding acceptable methods can be documented until they can be included in revisions to RG 1.205 or NEI 04-02. Methods that have not been determined to be acceptable by the NRC Staff or acceptable methods that appear to have been applied differently than described require additional justification to allow the NRC Staff to complete its review of the proposed method. Section 6.2 of the Fire Scenario report (PRA-A2-05-003) discusses three steps for deciding the damage threshold for electrical cabinets based on the location of the electronics related to the ignition source. Describe how sensitive electronics components are identified treated. If the impact of fire on sensitive electronics whose failure could have an impact on fire risk was not performed, provide an estimate of the impact on CDF and LERF, and ΔCDF and ΔLERF of considering fire-induced failure of electronics using recommended criteria from NUREG/CR-6850.

Response

For sensitive electronics mounted within a panel or other robust enclosure, the solid state component is failed where it is located within an ignition source zone of influence using the heat flux damage threshold of thermoset cables. Justification for using cable damage thresholds for temperature sensitive equipment located inside cabinets is provided in the response to Fire Modeling RAI 02 in Entergy letter dated November 7, 2013 (Reference 3).

Fire PRA FAQ 13-0004 (“Temperature Sensitive Equipment Zone of Influence Study Using FDS,” 2013) indicates that the heat flux damage threshold of thermoset cables might not be applicable to sensitive electronics that are mounted on the surface of the cabinet (front or back

wall/door) where the electronics may be directly exposed to the convective and/or radiant energy of an exposure fire. Walkdowns were performed (PRA-A2-05-016 *Walk-downs: Secondary Combustible Configurations Rev. 0)* which included a step to identify sensitive electronics and document those cases where electronics exist without a radiant shield barrier. No instance within ANO-2, where fire scenarios were developed, contained sensitive electronics mounted on the surface that would be susceptible to the convective and/or radiant energy impact.

Since the walkdowns did not identify sensitive electronics not enclosed within a robust enclosure, and because the use of cable damage thresholds for temperature sensitive equipment inside cabinets is justified, there are no impacts on the CDF/LERF and ΔCDF/ΔLERF.

PRA RAI 16 – Large Reduction Credit for Modifications

Section 3.2.5 of RG 1.205 states that risk decreases may be combined with risk increases for the purposes of evaluating combined changes in accordance with Regulatory Positions 2.1.1 and 2.1.2 of RG 1.174. Accordingly, both individual and cumulative risk effects should be evaluated in detail.

a) Given that the submitted application represents a change that combines risk increases with risk decreases, please provide the total increase and total decrease in the ΔCDF and ΔLERF.

b) Attachment W of the LAR summarizes the risk significant scenarios in the variant case. Please summarize the risk significant scenarios for fire areas II, SS, and G in the compliant case.

Response

a) The delta CDF/LERF results from the sensitivity study cited in LAR Section V.2.2 were re-evaluated in a manner that separates the reductions in risk due to plant modifications from increases in risk associated with variances from deterministic requirements (VFDRs) and risk of recovery actions. The new Auxiliary Feedwater (AFW) pump modification was inserted into the deterministically compliant configuration used to generate the delta risk calculations in the Fire Risk Evaluations. In the ‘compliant with new pump’ configuration, the AFW pump modification was credited in lieu of the existing Emergency Feedwater (EFW) / AFW systems to satisfy the decay heat removal performance criterion. The difference between the ‘compliant with new pump’ configuration and the post-transition configuration provides an estimate of the increases in risk associated with the non-EFW VFDRs and their associated risk of recovery actions.

The total risk increases and decreases are summarized in Table 1 below. These values do not reflect model revisions being performed to address NRC RAIs. Once the revised model is complete, these values will be updated accordingly.

The redundant DC modification for tripping the Reactor Coolant Pumps (RCPs) on loss of Component Cooling Water (CCW) was not changed in the new compliant case because the reduction in risk from this modification is small. Since the risk of the Operator action to trip

the RCPs is several orders of magnitude larger than random failure of the DC system, this modification essentially makes DC power available. Thus, this modification is like the VFDR-removing modifications discussed below and has a negligible impact on the delta risk values.

All remaining modifications relocate or protect cables. Thus, these modifications remove VFDRs making the post-transition case the same as the compliant case. Therefore, the modifications do not contribute to the delta risk values.

Table 1

ANO-2 DELTA RISK CALCULATIONS

Risk Reduction Due to Plant Modifications Separated from Risk Increase due to VFDRs and Recovery Actions

	CDF	ΔCDF	LERF	ΔLERF
Total difference in risk between compliant plant and post-transition plant (combined risk increases and risk decreases) - from sensitivity study cited in LAR Section V.2.2 [PRA-A2-05-010, Rev. 0]	4.76E-05	-2.62E-04	9.90E-07	-9.04E-06
Risk increase from VFDRs and recovery actions - from delta risk calculation with no offset from the new AFW pump modification [PRA-A2-05-019, Rev. 0, App. A]	4.76E-05	1.36E-05	9.90E-07	2.25E-07
Total ΔCDF/LERF Risk Increase		1.36E-05		2.25E-07
Total ΔCDF/LERF Risk Decrease (total difference in risk minus risk increase)		-2.76E-04		-9.27E-06

Two sensitivity studies were also performed which re-assess the delta risk evaluations documented in PRA-A2-05-010, Rev. 0, without the assumed failure of the components with ‘unknown cable routing’ (UNL). The first sensitivity study credited the UNL components in both the compliant and the post-transition baseline case (variant case). The second sensitivity evaluation credited the UNL components only in the compliant case, but the UNL components remained failed in the post-transition baseline case (variant case). The UNL sensitivity studies are documented in Appendix B of PRA-A2-05-019, Rev. 0, and the results of the sensitivity studies are listed in Table 2 below. This table shows that the negative delta risk result in PRA-A2-05-010, Rev. 0, is not solely due to the UNL failures.

Table 2

ANO-2 UNL Sensitivity Studies

	CDF	ΔCDF	LERF	ΔLERF
UNL Sensitivity Study I: Total fire risk and delta risk values without failing UNL components in the post-transition or compliant cases reported in PRA-A2-05-010, Rev. 0.	3.70E-05	-1.53E-04	7.44E-07	-5.36E-06
UNL Sensitivity Study II: Total fire risk and delta risk values without failing UNL components in the compliant cases reported in PRA-A2-05-010, Rev. 0. UNL components remain failed in the post transition baseline case (variant case) reported in PRA-A2-05-010, Rev. 0.	4.76E-05	-1.42E-04	9.90E-07	-5.11E-06

b) A summary of the risk significant compliant case scenarios in Fire Areas II, SS, and G is provided below. The scenarios selected were the most damaging scenarios in Fire Areas II, SS and G with respect to zone of influence. The risk values for these scenarios are listed in Table 3 (from the sensitivity analysis described in LAR Section V.2.2), and may not reflect the final values since these risk values do not reflect model revisions being performed to address NRC RAIs. Once the revised model is complete, these values will be updated accordingly.

<u>Fire Area II</u>

Fire Area II is the north switchgear 2A-3 room which contains only Fire Zone 2101-AA. The risk significant scenario in Fire Area II is a large fire that results in total loss of all cables in the zone, primarily vital switchgear 2A-3. Since switchgear 2A-3 is the red train switchgear, green train equipment is credited for safe shutdown following a fire in this area. As expected, the dominant risk contributors for Fire Area II are random failures of the green train safe shutdown equipment. The top cutsets include random failures of the steam-driven EFW pump 2P-7A. The top cutsets include any single random failure that can result in loss of decay heat removal through failure of the pump to operate, failures in the flow path to inject water into the steam generator (SG), or failure to prevent SG overfill resulting in failure to maintain the necessary steam pressure to operate the pump’s turbine (including Operator failure to take action in the Control Room to prevent an overfill of the SGs). Reactor Coolant System (RCS) integrity is maintained, but is dependent on an in-Control Room Operator action to trip the Reactor Coolant Pumps (RCP) on assumed loss of the Component Cooling Water (CCW) system needed for RCP seal cooling. An offsite source feed is available to bus 2A-2 which feeds vital green train safety bus 2A-4. Emergency Diesel Generator (EDG) No. 2 is available as an alternate power supply to 2A-4. Green train Service Water (Loop II) is available from Service Water pump 2P-4C. High Pressure Safety Injection (HPSI) pump 2P-89B is available to be aligned from the Control Room for injection into the RCS.

Fire Area SS

Fire Area SS contains Fire Zones 2100-Z (south switchgear room 2A-4), 2097-X (east DC equipment room), and 2102 (east battery room). The most risk significant compliant case scenario in Fire Area SS is loss of the entire south switchgear 2A-4 room (Fire Zone 2100-Z). This full room burn-up scenario comprises ≈75% of the total compliant plant risk in Fire Area SS. Since Fire Zone 2100-Z is the green train switchgear room, red train equipment is credited for safe shutdown for a fire in Fire Area SS. As expected, the dominant risk contributors are random failures of the motor driven EFW pump 2P-7B, and existing AFW pump 2P-75A, to inject water into the SGs for decay heat removal. Since the motor driven EFW pump is powered from vital bus 2A-3, random failures of red train power supply 2A-3 are the top risk contributing cutsets. Offsite power is available from bus 2A-1 to feed vital bus 2A-3, but both EDGs and the Alternate AC Diesel Generator (AACDG) are unavailable due to fire impacts. RCS integrity is maintained, but is dependent on an in-Control Room Operator action to trip the RCPs on assumed loss of the CCW system needed for RCP seal cooling. Red train HPSI is available to provide RCS makeup. Red train Service Water is available from Loop I Service Water pump 2P-4A.

Fire Area G

Fire Area G is comprised of several fire zones that make up the alternate shutdown area, most notably, the Cable Spreading Room (CSR, Fire Zone 2098-C) and the Main Control Room (MCR, Fire Zone 2199-G). Full room burn-up scenarios in the CSR and the MCR have the highest (and the same) compliant case CCDP in Fire Area G. Though a few scenarios in Fire Area G have a higher CDF than the MCR full room burn-up scenario because of varying ignition frequencies and non-suppression probabilities, those scenarios are bounded by the CCDP of the MCR and CSR full room burn-up fires. The MCR full room burn-up scenario is also known as the MCR abandonment scenario.

The compliant cases for the MCR abandonment scenario and the CSR full room burn-up scenario evaluate the risk assuming the green train systems are available. The top risk sequences include random failures of the steam-driven EFW pump 2P-7A. The top cutsets include any single random failure that can result in loss of decay heat removal through failure of the pump to operate, failures in the flow path to inject water into the SG, or failure to prevent SG overfill resulting in failure to maintain the necessary steam pressure to operate the pump's turbine (including Operator failure to take action in the MCR to prevent an overfill of the SGs). Vital buses 2A-3 and 2A-4 are required to operate the EFW isolation valves. Both vital safety buses are available through the following configuration: an offsite power source feeding 2A-3 from 2A-1 and EDG No. 2 feeding 2A-4. RCS integrity is maintained, but is dependent on an in-Control Room Operator action to trip the RCPs on assumed loss of the CCW system needed for RCP seal cooling. In the hypothetical compliant case for the MCR abandonment scenario, in-Control Room Operator actions are credited. Green train Service Water (Loop II) is available from Service Water pump 2P-4C. HPSI and the AACDG are not available. The compliant cases for all other fire scenarios in Fire Area G have these components available at a minimum and also have additional components available depending on the fire damage of the specific fire scenarios.

Table 3

Summary of Risk Values[1] for Select Compliant Case Scenarios

Zone	Scenario	Scenario Description	Zone Description	Area	IGF	NSP	SF	CCDP	CDF	CLERP	LERF
2101-AA	FRE-M	Base Scenario	North Switchgear Room (2A3 room)	II	1.32E-03	1	1	5.80E-02	7.65E-05	1.96E-03	2.58E-06
2100-Z	FRE-M	Base Scenario	South Switchgear Room	SS	1.38E-03	1	1	1.46E-02	2.01E-05	4.88E-04	6.73E-07
2199-G	FRE-M	FRE - Deterministically Compliant Case	Control Room-Abandonment	G	1.80E-05	1	1	1.12E-01	2.02E-06	3.92E-03	7.06E-08

1. Values are extracted from the Sensitivity Analysis identified in Section V.2.2 in Attachment W of the LAR (PRA-A2-05-010, Rev. 0)

PRA RAI 17 – Implementation Item Impact on Risk Estimates

Section 2.4.3.3 of NFPA-805 states that the PRA approach, methods, and data shall be acceptable to the NRC. Section 2.4.4.1 of NFPA-805 further states that the change in public health risk arising from transition from the current fire protection program to an NFPA-805 based program, and all future plant changes to the program, shall be acceptable to the NRC. RG 1.174 provides quantitative guidelines on CDF, LERF, and identifies acceptable changes to these frequencies that result from proposed changes to the plant's licensing basis and describes a general framework to determine the acceptability of risk-informed changes. The NRC staff review of the information in the LAR has identified the following information that is required to fully characterize the risk estimates.

Attachment S of the LAR identifies numerous proposed plant modifications. Some of the proposed modifications are fairly complex. Installing backup DC control power to the switchgear (S1-3) might, for example, require routing of cables that could, in turn be failed by some of the fires which the new equipment is being credited to help mitigate. Please provide the following:

a) Identify the proposed modifications that do not correct any VFDRs (i.e., that are installed solely to reduce risk).

b) Summarize how the design of the new features has been provided to the PRA analysts for use in modeling the risk impact (e.g., as brief descriptions or completed design package).

c) Summarize the new models that have been developed (e.g., what basic events, fault trees, event trees, and failure data).

d) Describe how the effect of all new cables has been evaluated (e.g., have areas that credit for the new equipment is being taken been identified as areas where required cables may not be routed).

Response

a) LAR Table S-1 modifications S1-14 and S1-16 are proposed to resolve NFPA code inconsistencies and modification S1-6 is proposed to resolve the potential for an IN 92-18 type of valve failure during non-power operations. The remaining modifications listed in LAR Table S-1 are risk-related. Of these, modification S1-10 (incipient detection in the CEDM room panels) is the only modification that has been proposed that does not, directly or indirectly, correct any VFDRs and is installed solely to reduce risk in the Fire PRA.

b) Many of the VFDR-related modifications simply relocate or protect cables so that fire impact is actually removed, effectively eliminating the VFDR in the area(s). Brief descriptions of these modifications were developed collaboratively between the PRA analysts and the modification scoping engineers. For relocated cables, the analysts ensured that new fire impacts were not created. For example modification S1-1 was developed as follows. First, the PRA analysts determined that a VFDR related to Emergency Feedwater (EFW) injection valves was causing unacceptable risk results in Fire Zone 2096-M in Fire Area HH. After studying the circuit drawings and component locations, the modification engineers proposed moving the affected relays and cables out of Fire Zone 2096-M and into adjacent Fire Zone 2098-C in Fire Area G. Next, the PRA analysts confirmed that the circuits for the subject EFW valves are already impacted by fires in Fire Zone 2098-C so the modification would not create new impacts. Finally, the PRA analysts removed fire impact to the EFW valves from the post-transition model for Fire Zone 2096-M and the modification engineers prepared the modification scoping document to move the affected relays and cables out of Fire Zone 2096-M and into Fire Zone 2098-C.

   Two of the VFDR-related modifications (S1-11 installing a new AFW pump and S1-3 installing backup DC control power to the switchgear) are more complex than the others and will be discussed in the remainder of this response. Scoping descriptions of these modifications were developed collaboratively between the PRA analysts and the modification scoping engineers as described below.

   For modification S1-11, the PRA analysts determined that an additional, diverse source of feedwater, with both local and Control Room control capability, could mitigate many VFDRs and reduce risk in several different fire areas. After studying the circuit drawings and component locations, the modification scoping engineers proposed a location for the new pump (Fire Zone 75-AA in ANO-1) and additional considerations for diverse power, valve locations, controls, etc. Next, the PRA analysts developed a fault tree for the new pump and auxiliaries. Then meetings were held in which the PRA analysts and modification scoping engineers refined the fault tree, the Fire PRA assumptions, and the modification description for consistency. The resulting Fire PRA fault tree is provided in the response to c), below. In developing the final design package, any deviations from the original assumptions will be communicated back to the PRA analysts, will be evaluated within the Fire PRA model, and the impact on risk will be assessed to ensure that the total risk will remain within regulatory limits.

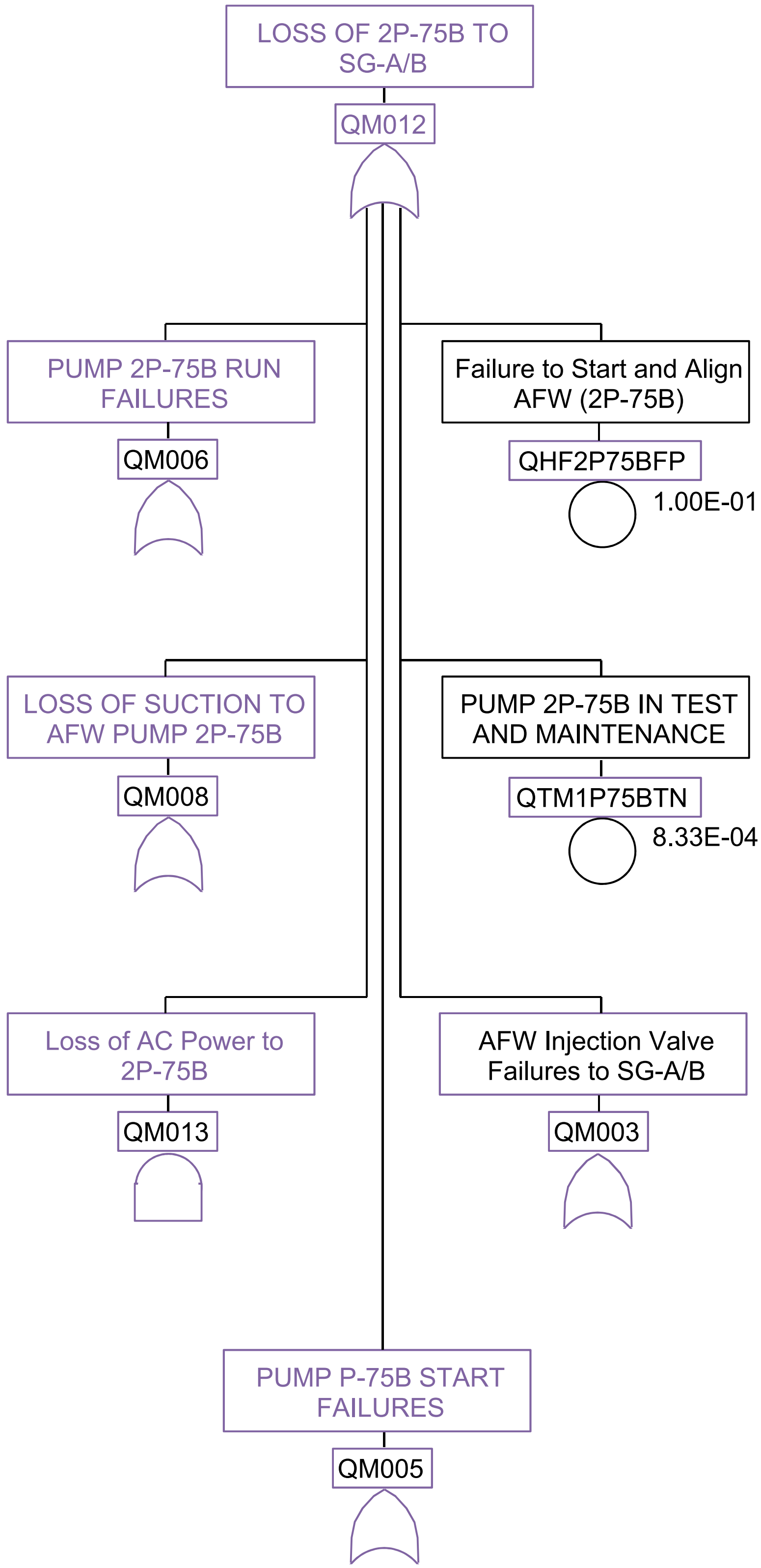
   For modification S1-3, the PRA analysts communicated a desire for a modification that could ensure one train of DC power remains available for remote breaker control. The modification scoping engineers proposed that the addition of a redundant DC power supply to the switchgear would be the most feasible manner in which to address this need. The modification scoping description provided in LAR Table S-1 was provided to the PRA

analysts and a redundant DC system was added to the fault tree that reflects the proposed design to ensure one train of DC power will remain available. The fault tree logic is provided in the response to c), below. Again, in developing the final design package, any deviations from the original assumptions will be communicated back to the PRA analysts, will be evaluated within the Fire PRA model, and the impact on risk will be assessed to ensure that the total risk will remain within regulatory limits.

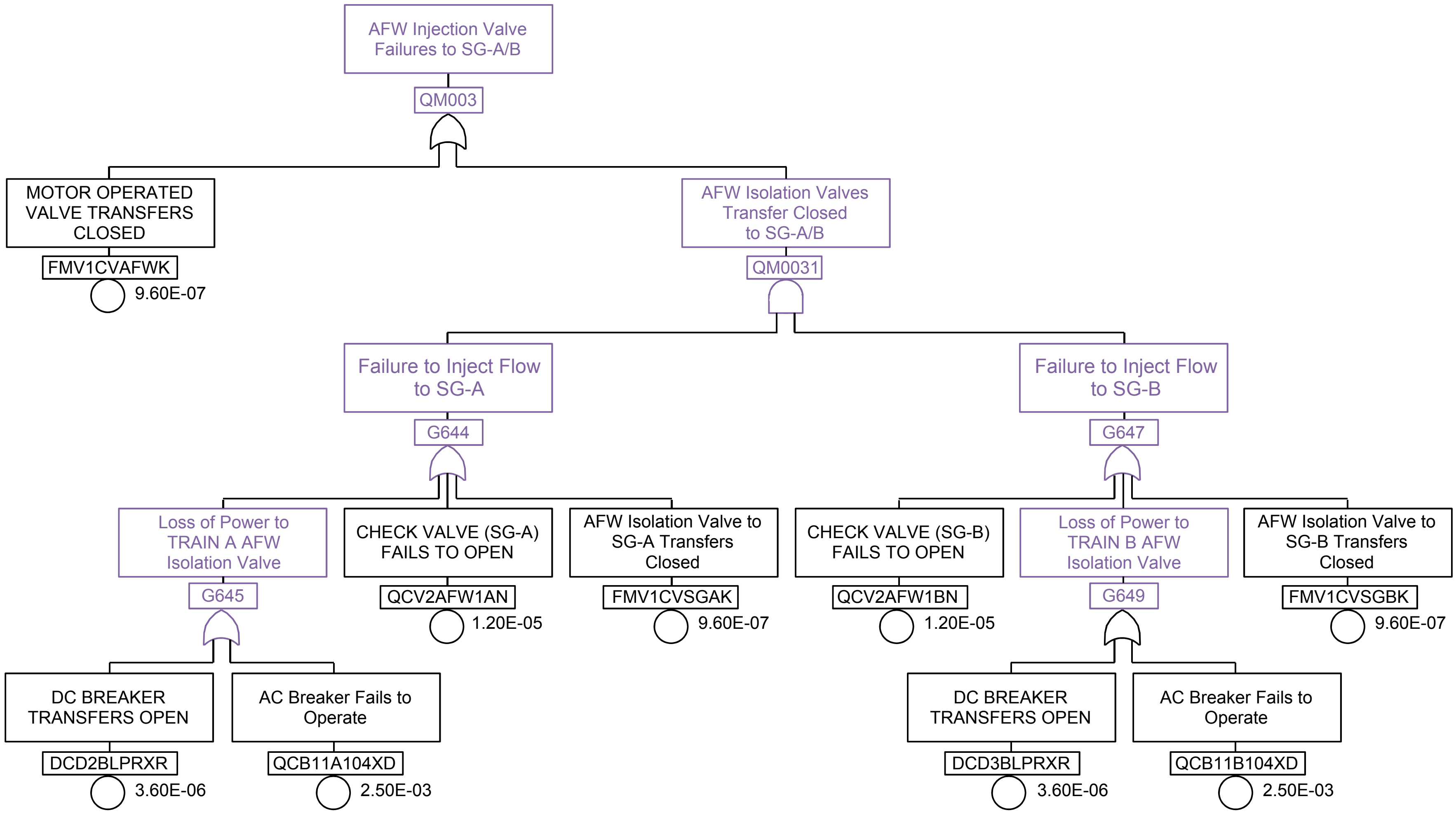
c) The following illustrations provide the fault tree logic and basic events for modification S1-11 (installing a new AFW pump) and the fault tree logic and basic events for modification S1-3 (installing backup DC control power to the switchgear). This logic was incorporated by revision of existing sequences to incorporate the new redundant capabilities. Thus, no new event trees were required. The failure rate data used is based on that associated with similar components modeled in the PRA. A review of this data will be performed once the final equipment is selected.

d) Areas in which modifications S1-11 and S1-3 have been credited have been identified as areas in which associated cables may not be routed. As described above, in developing the final design packages, any deviations from the original assumptions will be communicated back to the PRA analysts, will be evaluated within the Fire PRA model, and the impact on risk will be assessed to ensure that the total risk will remain within regulatory limits.

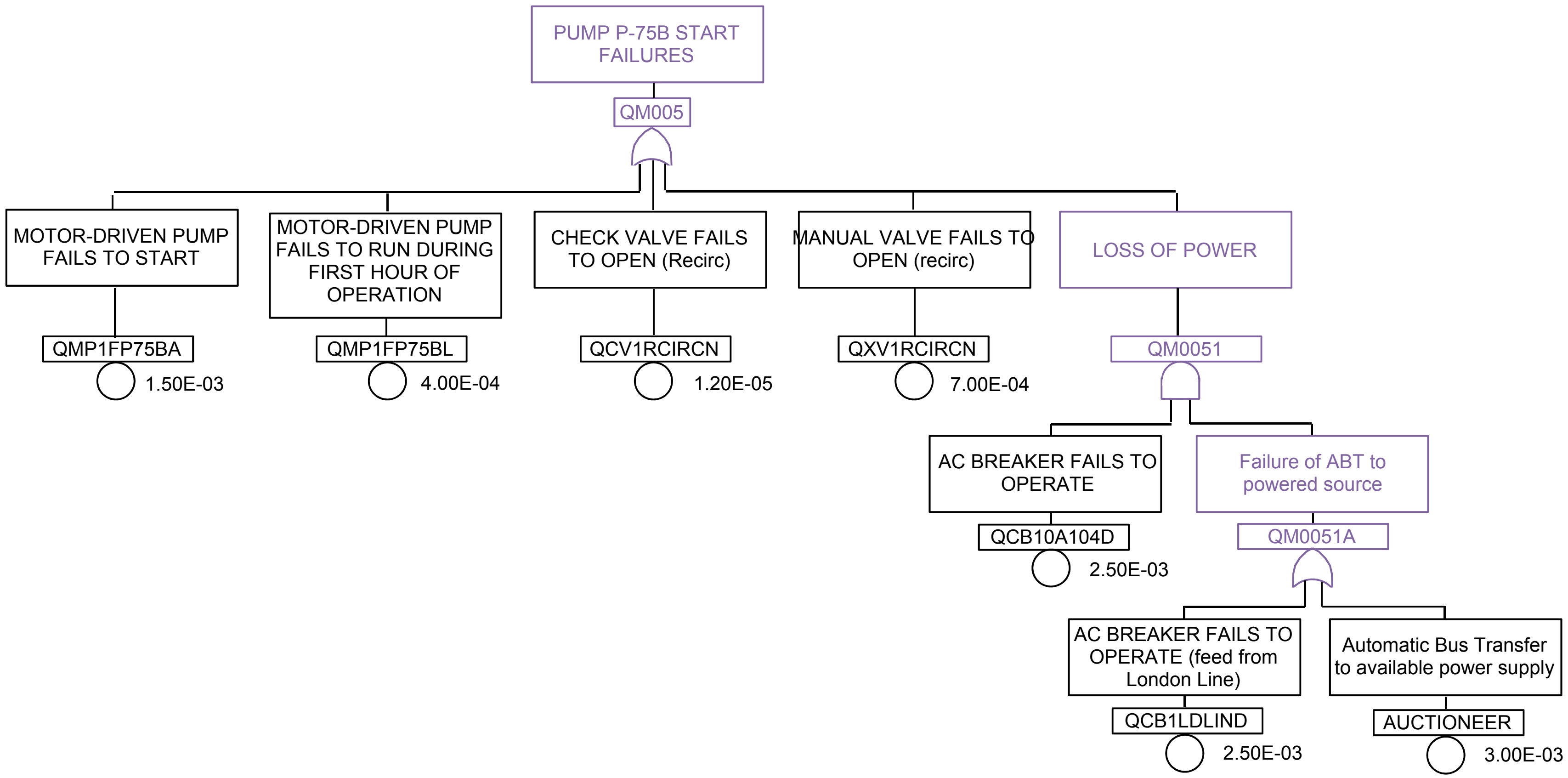
Modification S1-11 (Installing a new AFW Pump) Fault Tree Logic Addition



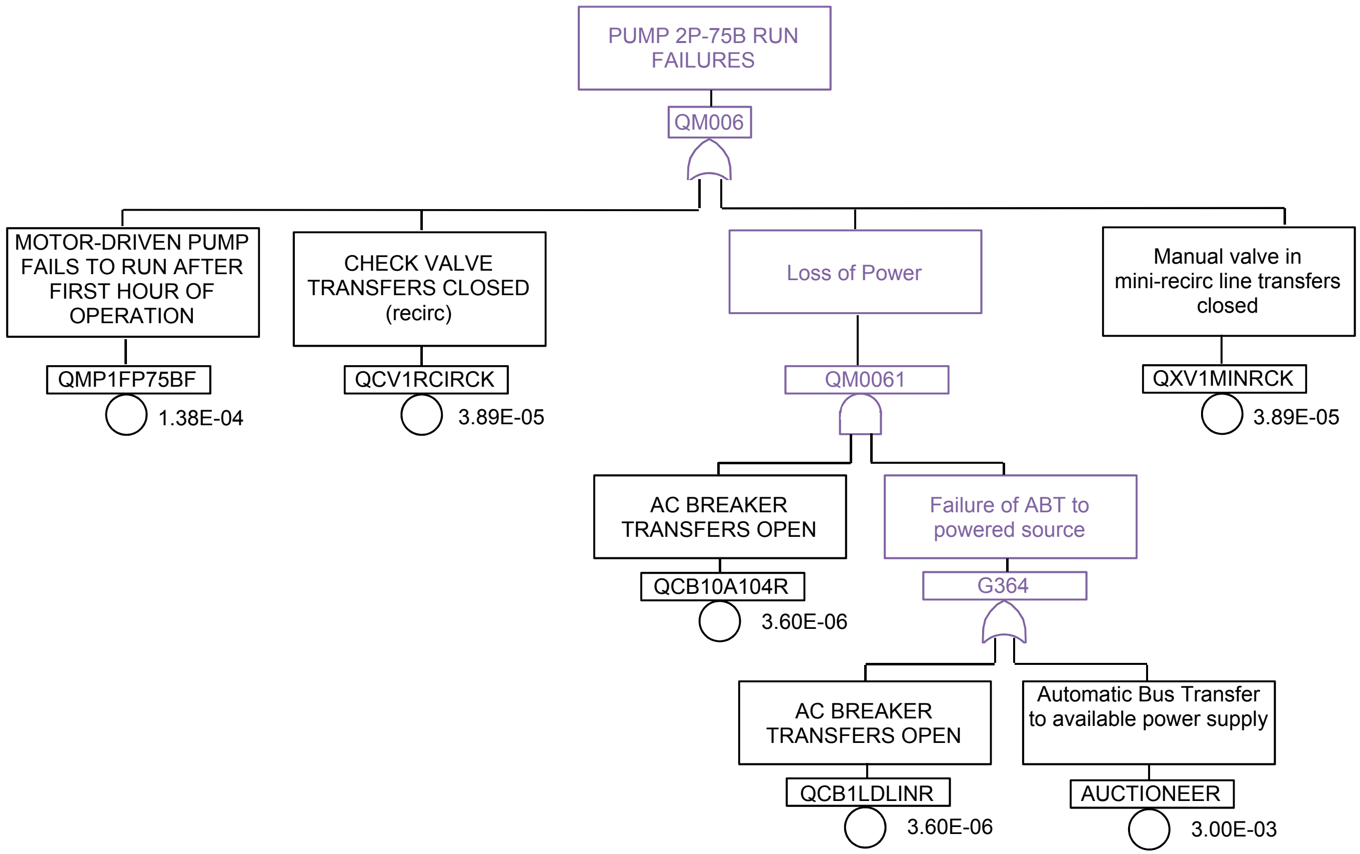
Modification S1-11 (Installing a new AFW Pump) Fault Tree Logic Addition



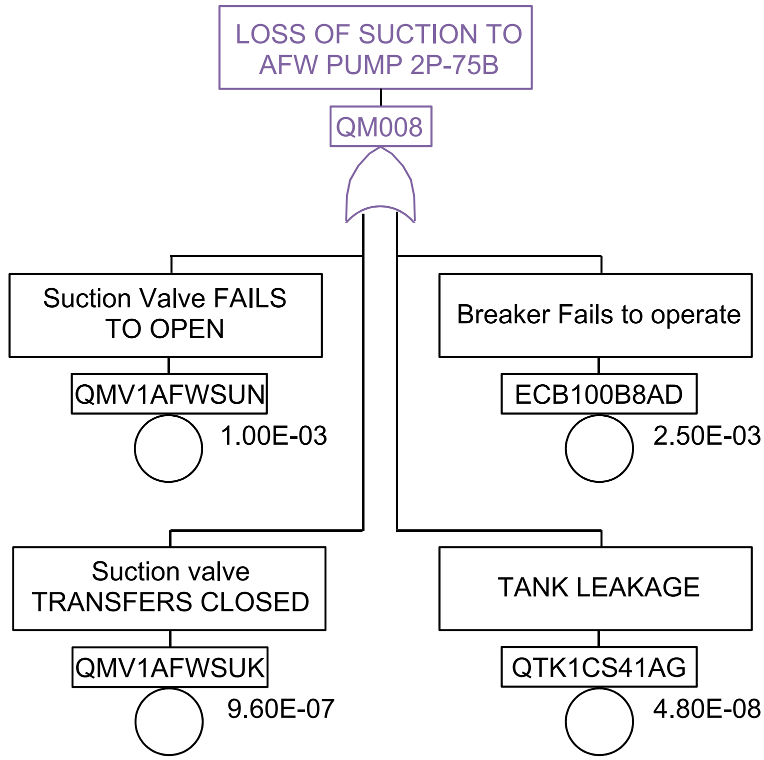
Modification S1-11 (Installing a new AFW Pump) Fault Tree Logic Addition



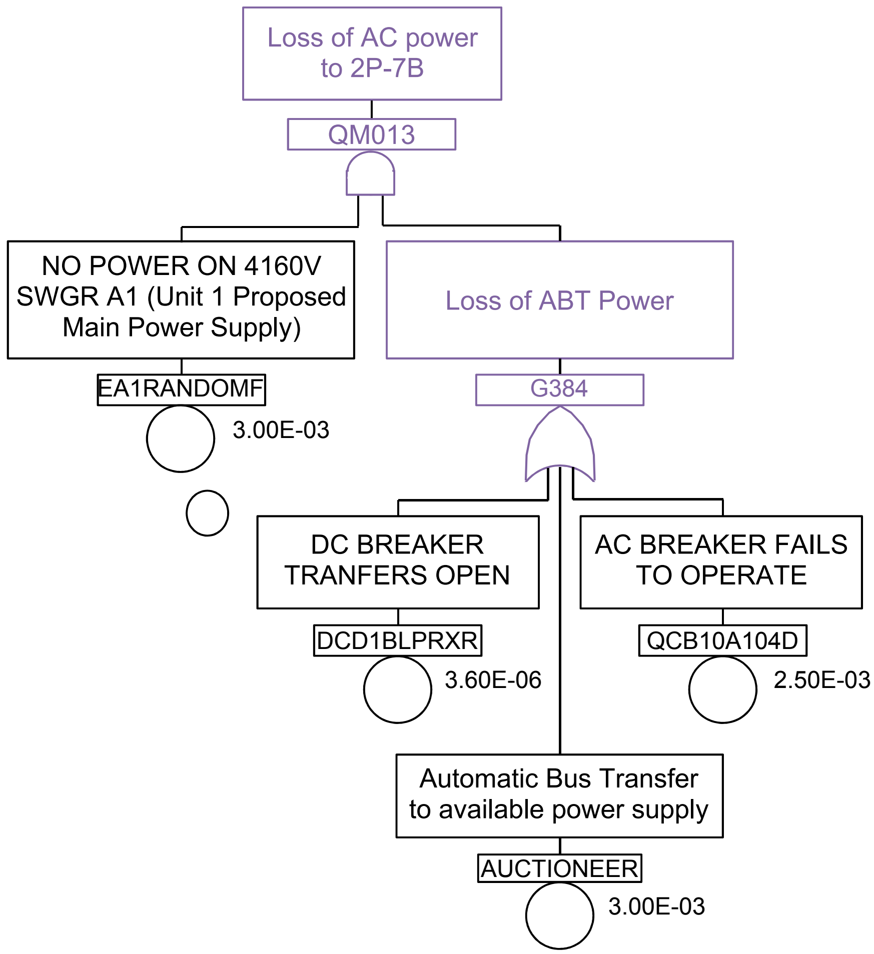
Modification S1-11 (Installing a new AFW Pump) Fault Tree Logic Addition



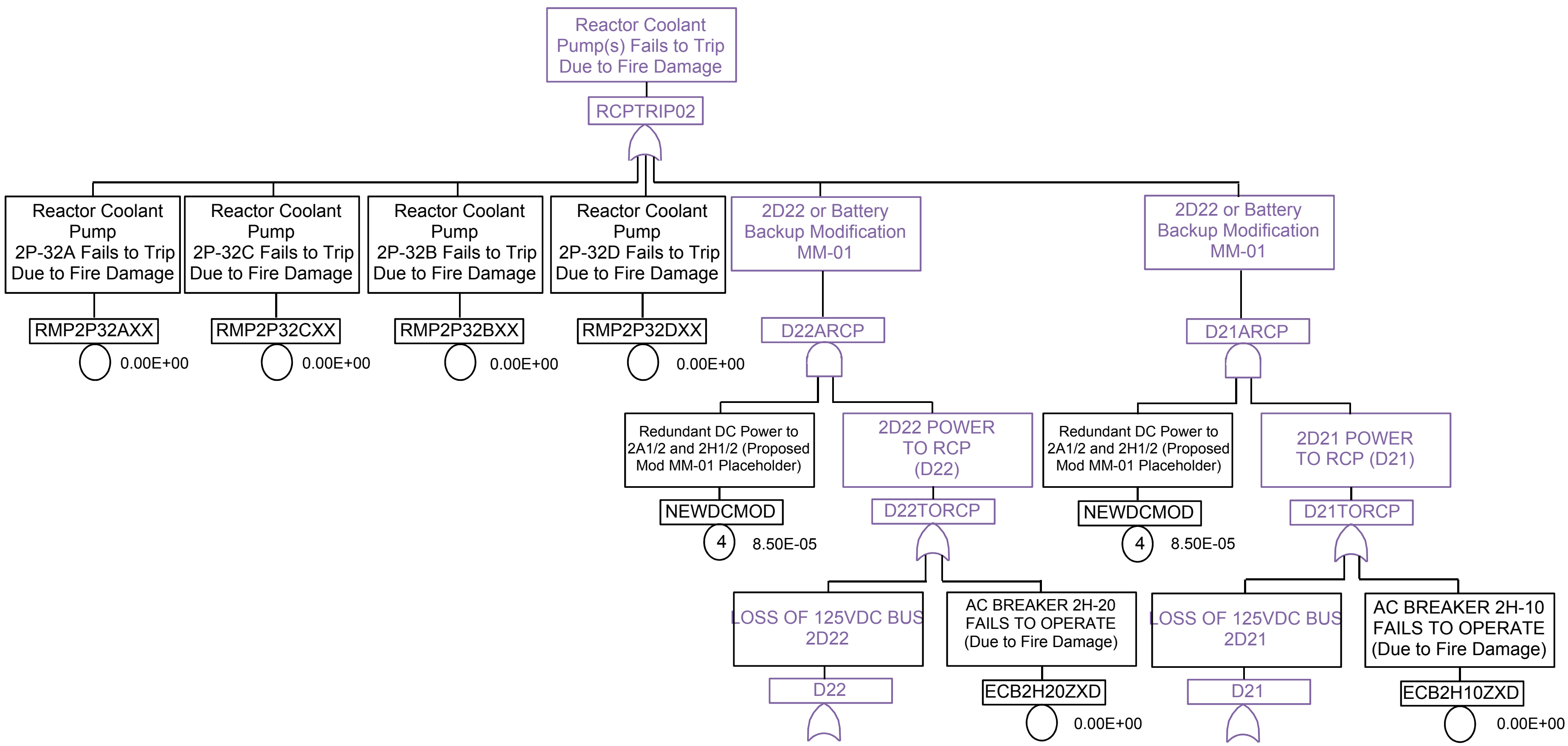
Modification S1-11 (Installing a new AFW Pump) Fault Tree Logic Addition



Modification S1-11 (Installing a new AFW Pump) Fault Tree Logic Addition



Modification S1-3 (Installing Backup DC Control Power to the Switchgear) Fault Tree Logic Addition



Summary

This letter provides the requested 120-day responses to NRC RAIs (Reference 2) associated with the ANO-2 NFPA-805 LAR dated December 17, 2012 (Reference 1). The updated fire scenario results will be provided in an update to Attachment W of the original LAR (Reference 1) when all Fire PRA revisions are complete (refer to Attachment 2 of this letter).

REFERENCES

1. Entergy letter dated December 17, 2012, *License Amendment Request to Adopt NFPA-805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)* (2CAN121202) (ML12353A041)

2. NRC letter dated September 11, 2013, *Arkansas Nuclear One, Unit 2 – Request for Additional Information Regarding Adoption of National Fire Protection Association Standard NFPA-805* (TAC No. MF0404) (2CNA091301) (ML13235A005)

3. Entergy letter dated November 7, 2013, *Response to Request for Additional Information – Adoption of National Fire Protection Association Standard NFPA-805* (2CAN111301) (ML13312A877)

4. Entergy letter dated December 4, 2013, *Response to Request for Additional Information – Adoption of National Fire Protection Association Standard NFPA-805* (2CAN121302) (ML13338A432)

Attachment 2

2CAN011401

List of Regulatory Commitments

LIST OF REGULATORY COMMITMENTS

The following table identifies those actions committed to by Entergy in this document. Any other statements in this submittal are provided for information purposes and are not considered to be regulatory commitments.

COMMITMENT	TYPE (Check one)		SCHEDULED COMPLETION DATE
	ONE-TIME ACTION	CONTINUING COMPLIANCE	
The updated fire scenario results will be provided in an update to Attachment W of the original LAR (Reference 1).	✓		Following completion of all Fire PRA revisions

1. Entergy letter dated December 17, 2012, *License Amendment Request to Adopt NFPA-805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)* (2CAN121202) (ML12353A041)