“Determining the Zone of Influence for High Energy Arcing Faults using Fire Dynamics Simulator” – Comment Resolution

The NRC’s Office of Nuclear Regulatory Research published draft research information letter entitled “Determining the Zone of Influence for High Energy Arcing Faults Using Fire Dynamics Simulator” on May 13th, 2022. Public comments were solicited via notice in the Federal Register (87 FR 29395, Docket Number NRC-2022-0096). Two sets of public comments were received, one from Engineering Planning and Management, Inc. (EPM), and one from the Nuclear Energy Institute (NEI). Their original submissions can be reviewed in the NRC’s Agencywide Documents Access and Management System (ADAMS) under the following accession numbers:
Comments from EPM: ML22165A134
Comments from NEI: ML22165A208

Their respective comment have been reproduced in the table below, along with their resolution.

No.	Reviewer	Line #, Page number or Section number	Reviewer Comment	Suggested Change	Resolution
1.	EPM	2.2.1 Page 41	While the assumption of low speed flows makes sense for thermal impacts, has consideration been given to the impact that the a pressure wave would have, including the force of potential metal shrapnel from the cabinet enclosure.	See comment and resolution.	The WG reviewed available test results and operating experience with regard to HEAF and arc flash pressure wave effects. The WG concluded the tests provide limited evidence of overpressure effects and no evidence of overpressure creating conditions (projectiles) that could damage external PRA targets during a HEAF. In general, the WG did not identify HEAF overpressure as a concern. Additionally, the lack of evidence of ensuing fires from arc blast events and the evaluation of the multi-room hazard via the fire PRA multi-compartment analysis, provides the working group with confidence that any potential hazard of HEAF pressure effects is adequately covered by the thermal zones of influence. Note that the effects of the pressure wave on the HEAF enclosure are addressed by assumption. For LVSWGR, the door to the breaker cubicle with the arc is opened at the start of the event; for MVSWGR, the front door is opened. To improve clarity in the FDS report, an appendix has been created that documents the WG analysis of the pressure wave effects. Reference to this appendix has been added to sections 2.1 and 2.3.1.

No.	Reviewer	Line #, Page number or Section number	Reviewer Comment	Suggested Change	Resolution
2.	EPM	2.2.3 Page 43	Voltage field/magnetic field impacts can have a significant affect on plasma shape/direction and particle speeds. This can have various impacts on the potential ZOIs. A peer review of the approach by others who typically model plasmas should be conducted and documented. There has been research and modeling of this type for plasma thrusters in the aerospace industry.	See comment and resolution.	The effects of the magnetic field are not directly modeled as described in Section 2.3.3. However, these effects are considered when developing the HEAF scenarios, in particular where the HEAF is located (see sections 5.1.1.1 and 5.1.2.1 for basis of HEAF selected locations). In addition, several sensitivity scenarios are included in the LV SWGR modeling in which the arc is pushed out of the initial compartment into a second compartment (see section 5.1.2.1 and 6.2.2.3). The arc migration is in part a reflection of the magnetic forces present during the arc event. To clarify that the magnetic effects are accounted for in the analysis approach, a sentence will be added in Section 2.3.3 that notes that although magnetic forces are not modeled, they are accounted for through the selection of the arc location as described in Sections 5.1.1.3, 5.1.2.3, and 5.1.3.3.
3.	EPM	2.2.3 Page 43	Discussion is provided regarding the lack of FDS capability for dynamic 3-phase arcs, but no discussion is provided on the potential impact to the model results.	See comment and resolution.	Similar to the treatment of magnetic forces, the effects of 3-phase arcs are not modeled directly, but the overall effect is accounted for in the selection of the arc location and volume. The FDS analysis involved the determination of the exposure conditions at relative far-field locations (enclosure boundary and outside the enclosure containing the arc) over a time scale that represents 60 or more phase cycles given the voltage is 60 Hz. The 3 phase effects may produce significant near field exposure variations over a few cycles, but these effects would be averaged over the distances and timescales of interest. To improve clarity, a sentence will be added to Section 2.3.3 that notes the effects of 3-phase arcs are bounded by the selection of the arc volume location.

No.	Reviewer	Line #, Page number or Section number	Reviewer Comment	Suggested Change	Resolution
4.	EPM	3.2 Page 47	The basis for the single point specific heat for Copper (I) oxide gas is not provided. If it is an assumed value this should be noted directly.	See comment and resolution.	This is an assumed value selected that is typical for metals and non-metallic oxides given a lack of available data on metal oxides. However, as described in Section 3.7.2.3, there is no heat exchange between the melted metal particles and the surrounding vapors, which would result in an overestimate of the gas temperature in the regions of interest. The vapors that combust are conservatively injected from the drop at the drop melting temperature which minimizes the temperature differential between the gas temperature and the injection vapor temperature. The uncertainty introduced with an assumed copper oxide heat capacity is expected to be secondary and bound by these conservative treatments. The description of the copper oxide heat capacity in Section 3.2 is updated to show it is an assumed value and that given the small mass fraction of oxide in the gas phase, errors associated with the specific heat should be small.

No.	Reviewer	Line #, Page number or Section number	Reviewer Comment	Suggested Change	Resolution
5.	EPM	3.2 Page 47	Copper oxide is naturally found in 2 different forms, Copper (II) Oxide: CuO and Copper (I) Oxide: Cu2O, depending upon the oxidation state of the copper cation. Only Cu2O is discussed by this report. The relative contribution (or exclusion) of CuO is not defined/demonstrated.	See comment and resolution.	The WG identified the two potential copper oxidation states during the feasibility studies. There was research data that supported CuO as a dominant reaction and data that supported Cu2O as a dominant form, though at high temperatures Cu2O appeared to be predominant. Given the differences in the reaction rates were small as compared to the reaction rates of aluminum, which was a focus of this analysis, it was determined to use Cu2O as the dominant oxide form. This selection maximized the difference between copper and aluminum and thus was expected to maximize the differences in aluminum and copper electrodes. Since the overall result of the analysis concluded that the ZOIs for aluminum and copper are similar, the impact of the oxide reaction is secondary and would not affect the overall results. A clarification is added to Section 3.2 that indicates the oxide with a lower reaction energy is selected to maximize the differences between aluminum and copper. However, the reaction energy of both copper reactions is small compared to aluminum and given the small concentration of metal oxide in the gas phase, the difference in energy between CuO and Cu2O is small compared to the total arc energy.
6.	EPM	3.5 Page 48	The heat of reaction for Cu2O as noted is 1340 kJ/kg . However for CuO it would be approximately 2460 kJ/kg. If Cu2O is expected to be the dominant product, this should be noted. Currently the relative contribution (or exclusion) of CuO is not defined/demonstrated.	See comment and resolution.	See response to comment 5. Note that the energy evolved during the combustion of the metal vapors was a small fraction of the overall energy budget. As such, the results were not expected to be sensitive to the copper oxide reaction energy for the assumed copper oxide. This may be seen by comparing similar configurations in which an aluminum electrode is used, which has a higher combustion fraction (75% vs. 25%) and a significantly higher heat of reaction (31 MJ/kg vs, 1.34 MJ/kg).

No.	Reviewer	Line #, Page number or Section number	Reviewer Comment	Suggested Change	Resolution
7.	EPM	4 Page 63	The validation results focuses on a few HEAF experiments in controlled environments and a couple industry events. Has consideration been given to any potential additional variables in live Nuclear Power Plants that may increase severity of the HEAF seen in other events. Back in 2017 there was a HEAF event at Turkey Point that was powerful enough to blow open a fire door and is what sparked the potential aluminum increasing the HEAF severity discussion. Some of the most severe events should be discussed somewhere in the report. Perhaps some form of severity factor is needed to capture these anomalies.	See comment and resolution.	The event at Turkey Point (FEDB #51634) is described and assessed in the HEAF Frequency and Consequence Modeling Report (i.e., the PRA report). Additional discussion is provided in Appendix E of this report in the context of pressure wave effects. This appendix is noted in Sections 2.1 and 2.3.1.
8.	EPM	4.5 Page 79	Consider adding a summary table of the bias factor and standard deviation for each phenomena to the end of this section as a quick reference for the end user.	See comment and resolution.	A single bias factor and standard deviation is used in the determination of the ZOIs. This is discussed in new Section 4.1.4. It is not recommended at this time that a user select different uncertainty parameters and adjust the results separately from what is done in the report. However, a table is provided that lists the bias and standard deviation for each test duration and rack grouping (Table 4-3).

No.	Reviewer	Line #, Page number or Section number	Reviewer Comment	Suggested Change	Resolution
9.	EPM	4.5 Page 79	A bias factor of only 0.57 for the predicted exposure suggests gaps in the FDS capabilities may be significant. Other FDS-based validation for NPPs in NUREG-1824 are much closer to 1.0 for most phenomena (except where overprediction is conservative such as smoke). Additional discussion may be warranted regarding the acceptability of the model results.	See comment and resolution.	The analysis approach incorporates a larger number of assumptions with respect to the arcing phenomena and the response of the enclosure containing the arc than the types of applications covered in NUREG-1824 Supplement 1. These assumptions tend to result in greater uncertainty in the results that is reflected in the small bias factor. In addition, the timescales over which the analysis is concerned are short and comparable to the breach times for the metal enclosures. As noted in Section 4.1.4 of the report, small differences in predicted breach time, which may be due to assumptions associated with the arc location, the response of the metal enclosure, and the assumed arc power, result in large differences in the predicted target exposure. When these effects are incorporated into the model results with the model bias, the overall predictions are reasonable and useful for developing insights for different enclosure configurations and arc power. An updated description is provided in Section 4.5 that summarizes the use of the bias factor and notes the reasons that it is low relative to NUREG-1824 S1 data.
10.	EPM	7 Page 203	The summary mentions the future PRA guidance but it should be noted here, like it is in the scope, that this guidance will be in a separate report. If at all possible before this report is finalized it would be helpful to reference the report name/number for those looking to use the guidance.	See comment and resolution.	At this time, the PRA report is being prepared for public comment and does not have a number. The latest information on the PRA report will be incorporated into the reference details when the FDS report is finalized for publication.

No.	Reviewer	Line #, Page number or Section number	Reviewer Comment	Suggested Change	Resolution
11.	NEI	Executive Summary (page xxix, 2nd bullet)	This section includes a statement that “for vertical-lift breaker style switchgear in the supply configuration, there is no vertical (top) ZOI component.” It is unclear if this is true for medium voltage switchgear.	Clarify whether or not this is applicable to medium voltage switchgear.	Intent is medium-voltage SWGR. Added clarification.
12.	NEI	Page 2-1	The assumption that the pressure wave does not have an impact on PRA targets is not clearly justified.	Provide a technical basis for the assumption.	The basis for excluding the pressure wave effects from the ZOI analysis is developed and documented in a new appendix (Appendix E). Reference to this appendix has been added to Section 2.1.
13.	NEI	Section 5 Heading	“Development” is misspelled	Correct spelling	Corrected spelling.
14.	NEI	Section 6.1.3.3 (Page 6-34)	This section includes a statement that “for vertical-lift breaker style switchgear in the supply configuration, there is no vertical (top) ZOI component.” It is unclear if this is true for medium voltage switchgear. Table 6-1 shows non-zero ZOIs for TOP of “PCCBB Supply.” Table 6-1 also shows zero front ZOI for the vertical-lift, load configuration.	Clarify whether or not this is applicable to medium voltage switchgear.	Applies to MV SWGR. Clarified (see comment 11).
15.	NEI	Section 6-3	It is not clear if this report included re-evaluation of the ZOI descending from Non-Segregated Bus Ducts as suggested by Supplement 1 to NUREG/CR-6850.	Include statement specifying findings related to this re-evaluation, or explicitly state that it was not re-evaluated.	The descending ZOI from bus ducts is not re-evaluated and remains generally the same (i.e., the ‘waterfall’ component). The PRA report discusses the application of this ZOI component to bus ducts. The primary difference involves the locations where this is postulated. A new section 2.2 is added that describes the ZOI components, and which are covered in this report.