Technical Evaluation for Generic Issue: Pre-GI-018, "High-Energy Arc Faults Involving Aluminum"

Table of Contents:

1. Summary of the Issue

The U.S. Nuclear Regulatory Commission (NRC) has identified a potential issue where existing regulations, guidance, and analytical models may not bound the hazard. This issue exists for electrical equipment that include components made of aluminum when subjected to high-energy arc fault (HEAF) conditions. The effects of HEAF events are approximated by using a zone of influence (ZOI) model, which delineates a volume around the HEAF-initiating location within which components, cabling, and other equipment are assumed to be damaged by the release of energy. Recent testing and review of operating experience indicates that the ZOI for target damage may be larger than the information presented in the current methodology for HEAF analysis as part of Appendix M of NUREG/CR–6850 (EPRI 1011989) "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Volume 2: Detailed Methodology."

NUREG/CR-6850 postulates damage potential will be limited to 0.9 meter (m) or 3.0 feet (ft.) horizontally and 1.5 m or 5.0 ft. above the enclosure. Recent tests have shown that the presence of aluminum resulted in a more energetic plasma than expected, causing a larger amount of damage and the transport of high temperature gas/particles/plasma farther than previously assumed. Also, test results showed a dispersal of electrically conductive aluminum byproducts, which can possibly result in unanalyzed additional failures. Fire hazards analysis performed under Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.48, "Fire Protection" and 10 CFR Part 50, Appendix R, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," require licensees to demonstrate the ability to perform safe shutdown functions and minimize radioactive material releases to the environment. A potential increase in ZOI for HEAF events could affect these analysis.

2. Background

HEAFs are energetic or explosive electrical equipment faults characterized by a rapid release of energy in the form of heat, light, vaporized metal, and pressure increase due to high current arcs between energized electrical conductors/components and neutral or ground. HEAFs have the potential to cause extensive damage to electrical components and distribution systems, as well as to adjacent equipment and cables. The significant energy released during a HEAF, along with the ejection of high-temperature projectiles, can act as an ignition source to combustibles in the ZOI, resulting in secondary fires and potentially affecting the functionality of nearby electrical equipment.

The HEAF fault scenario typically consists of two distinct phases, each with its own damage characteristics.

Phase1: A short, rapid release of electrical energy which may result in catastrophic failure of the electrical enclosure, ejection of hot projectiles (from damaged electrical components or housing) and/or fire(s) involving the electrical device itself, as well as any external exposed combustibles, such as overhead exposed cable trays or nearby components, that may be ignited during the energetic phase. The energy released during a HEAF is sufficient to rapidly vaporize materials within the arc path. The vaporized metal and heated air expand rapidly due to the amount of heat generated in the electrical arc, producing a pressure wave. Molten metal ejecta are propelled outward, potentially causing damage to equipment in the surrounding area.

Phase 2: In addition to the fire within the equipment originating the HEAF, the ejection of hot particles or piloted ignition of combustibles may cause ignition of combustible materials within the ZOI.

Operating experience from the nuclear industry reflects a considerable number of events showing explosions and rapidly developing fires resulting from HEAFs in electrical devices, such as switchgears, load centers, bus bars/ducts, transformers, motor control centers and cables, operating on voltage levels of 440 volts and above.[1] Operating experience has shown that protective devices have not always worked as designed. Incorrect breaker settings and fuse sizing due to design errors can increase the likelihood of a HEAF to occur. Operating experience has also shown that the fault can be initiated in a location that will not be protected by fault clearance devices, which allows for extended fault exposure times. For example, a HEAF event that occurred at Diablo Canyon on May 15, 2000 (ADAMS Accession No. ML003725220) exhibited successful breaker openings of the switchyard and main generator field breaker immediately at the start of the event. However, coast down of the main generator continued to feed the arc fault on the 12 kV bus.

3. Influence of Aluminum on HEAFs

Typically, electrical conductors are either aluminum or copper. The use of aluminum in electrical equipment and duct work has no adverse impact on the ability of that equipment to perform its design function. The use of aluminum components does not cause the electrical equipment to malfunction or become incapable of performing its design function. Hence, the use of aluminum is not an equipment qualification, seismic qualification, or quality control issue.

However, recent testing performed by the NRC in cooperation with international groups (e.g., Nuclear Energy Agency (NEA) within the Organisation of Economic and Co-operative Development (OECD)), has shown that introducing aluminum into arc fault events resulted in a significantly larger release of energy than expected. The source of aluminum can include components that form 1) part of the normal current carrying pathway (such as bus bars, breaker armatures, contacts, cable, etc.) or 2) part of the current pathway as a result of a ground fault (housings, structural framework, adapters, cradles, wire ways, conduits, draw-out or racking mechanisms, etc.). The larger amount of energy released during testing resulted in more damage to surrounding equipment and cables, increasing the zone of influence (ZOI) of

---

1 NUREG/CR-6850 and EPRI TR-1011989, U.S. Nuclear Regulatory Commission and Electric Power Research Institute (EPRI/NRC-RES), "Fire PRA Methodology for Nuclear Power Facilities Report," September 2005 (ADAMS Accession No. ML15167A401).

damage. The extent of damage exceeded the expected ranges currently assumed in performance-based fire protection analyses. In addition to the additional energy, testing of components involving aluminum resulted in the dispersal of dust-like aluminum particles throughout the test cell area. This aluminum byproduct was conductive and caused short circuiting and grounding of electrical equipment in the test area.

In regards to the applicability of a HEAF involving aluminum components in U.S. nuclear power plants (NPPs), the staff is uncertain of the extent of aluminum components currently in use in electrical distribution systems. However, based on preliminary information gathered from licensees by NEI (ADAMS Accession No. ML17165A140) and from NRC staff review of licensee event reports (LERs), Electric Power Research Institute's (EPRI's) Updated Fire Events Database,[2] NRC inspectors, and other knowledgeable NRC staff, the NRC staff has identified aluminum being used as bus duct enclosure material and within electrical switchgear equipment (480 V and above) in at least 13 nuclear sites.

4. Potential Mitigating Measures for HEAF Events

Improper operation and maintenance practices represent the most significant contributors to HEAF events. Additional contributing causes include the use of improper tools and equipment during maintenance; introduction of conductive foreign material; insulation breakdown due to aging; failure of tripping mechanisms; loose bolted connections due to vibrations or inadequate maintenance practices; corrosion; improper work practices due to inadequate training; and a lack of preventative maintenance. Any of these contributors could lead to the development of a low resistance path between conductors and grounds, creating an HEAF event.

Licensees can implement a variety of preventive measures to minimize these contributing causes, thereby reducing the likelihood of uncontrolled fault events that could progress to HEAFs. Typical methods employ electrical configuration and control measures in the form of installed electrical circuit breakers to sense and provide protection for phase-to-ground and phase-to-phase faults. Typical circuit breakers are designed to operate within 3-to-20 cycles. However, there are fast-acting circuit breakers that can operate within 3-to-5 cycles, which would minimize the damage associated with HEAF events. Once licensees install protective devices that are rated adequately with the proper settings, only the protective device nearest the fault location should open to isolate a faulted circuit from the system (i.e., selective coordination). This permits the rest of the system to remain in operation, providing maximum service continuity (Ref: IEEE Std. 279 and IEEE Std. 603). Another protective measure uses fast acting fuses to help reduce the exposure time of an arc flash event. However, incorrect design, maintenance practices, or improper settings of the protective devices can lead to extended arc durations and increase the amount of energy released during an arc flash.

Manufacturers are continuously working to improve switchgear designs, incorporating internal component partitioning, and using different insulating mediums and alternative housing alloys meant to contain an arc more effectively. Still, there are many factors that are not completely understood about the dynamic nature of HEAFs. Additional research would be beneficial to understand fire conditions developing within the initiating compartment, the spread of flames to adjacent electrical components, and the ionizing soot production.

---

2 The Updated Fire Events Database: Description of Content and Fire Event Classification Guidance. EPRI, Palo Alto, CA: 2013. 1025284

5. NRC/OECD HEAF Testing

The NRC's Office of Nuclear Regulatory Research (RES) in participation with the OECD has been conducting testing of electrical components under electrically faulted conditions from 2014 to 2016. The purpose of the testing was to gain a better understanding of the HEAF phenomena and perform confirmatory testing for the ZOI used in risk analyses. The OECD published the test report in May 2017, which documents the results of 26 recent experimental tests.[3] During these tests, some unexpected results were obtained when equipment that included components made of aluminum were subjected to HEAF conditions, as compared to the tests where the electrical conductors were made of entirely of copper. These unexpected results have led the NRC staff to believe that the HEAF scenarios used in the current EPRI 1011989 / NUREG/CR-6850 may be non-conservative for components containing aluminum, thereby underestimating the potential risk. Summaries of the test results involving aluminum are discussed below.

Test 23—IP-20 Switchgear

Test 23 of the HEAF experimental series consisted of a low voltage 480 VAC switchgear cabinet that utilized an aluminum bus bar. The test resulted in failure of the cabinet walls such that the plasma wave front created by the arc fault was expelled out of the cabinet a significant distance of several feet, resulting in the melting and destruction of the Inconel temperature sensors which were located 0.9 m (3 ft.) from the enclosure. This test was the only low voltage experimental test where this level of damage was exhibited. In all other low voltage tests (non-aluminum components) the temperature sensors located 0.9 m (3 ft.) horizontally from the cabinet were not damaged and were able to be used in subsequent tests. The test video showed the vapor/plasma cloud migrating well beyond the current limit of 0.9 m (3 ft.) horizontal and 1.5 m (5 ft.) vertical distance for the ZOI.

In addition to the physical damage caused by the HEAF event, there was a significant layer of conductive aluminum byproducts that coated structures and components within the test cell, especially on electrical equipment. This aluminum byproduct layer was sufficient enough to cause problems to exposed electrical equipment within the test cell, requiring a major activity to repair or replace components.

The construction of the enclosure may have allowed the resultant HEAF energy to more readily escape the cabinet environment and damage components further from the point of origin. The side walls of the individual unit tested consisted of sheet metal intended for internal enclosure separation. Normally this section would have fit together in a longer row of vertical electrical enclosure sections. The end sections are typically constructed of thicker materials which could have potentially been more resistant to the arc energy. However, Test 23 also showed that the energy released from the HEAF vaporized and burnt through a more robust piece of 0.32 cm (0.13 inch (in.)) steel used to close a functional gap in the cabinet and create a closed boundary for pressure measurements. Regardless of the exterior material composition, the extent of damage observed in Test 23 was well beyond

---

[3] NEA/CSNI/R (2017), "Report on the Testing Phase (2014 to 2016) of the High Energy Arcing Fault Events (HEAF) Project: Experimental Results from the International Energy Arcing Fault Research Programme (http://www.oecd-nea.org/nsd/docs/indexcsni.html)

the damage witnessed in other experiments carried out at similar voltage and current levels with copper conductors.

Compared to the results from similar tests involving electrical enclosures only containing copper, Test 23 was a clear outlier, based on the increased damage observed to the measurement devices and video recording equipment. Noteworthy was the damage to the test cell itself from the spread of an electrically conductive film of aluminum byproduct. The results of Test 23 were unexpected, and the damage to the test facility's medium voltage power supply precluded any further scheduled testing until repairs could be completed.

Test 26—Bus Duct

Test 26 involved a bus duct section removed from the 4.16 kV switchgear room of the decommissioned Zion nuclear plant. The bus duct section consisted of segmented (non-segregated) copper bus bars enclosed within an aluminum bus duct housing. The bus duct section was secured to the floor using wooden structural members and the ends were covered with a sheet of electrically insulating “red board.” This piece of red board was installed to create a pressure boundary within the bus duct unit and limit the free release of energy once the fault was initiated. Immediately upon initiating the HEAF event, the hot gas mixture forced the red board away, allowing the arc and associated hot gas/plasma mixture to jet out of the bus duct, blowing hot gas/molten metal linearly from the bus duct opening. The arc was initiated on the copper conductors and progressed to the grounded aluminum bus duct housing as it became involved in the arc path. During the arc event, 3.81 cm (1.50 in.) of copper material and 17.78 cm (7 in.) of aluminum material were vaporized.

The involvement of the aluminum housing material in the arc path and subsequent vaporization of aluminum material caused Test 26 to exhibit a much larger damage state than other components tested with similar voltage and current ranges. The hot gases/plasma ejected approximately 9 m (30 ft.) horizontally, impacting the wall of the test facility. The instruments associated with temperature and heat flux, located approximately 0.9 m (3 ft.) away from the cabinet and electrical equipment/cable materials on the test facility walls were extensively damaged. Test 26 also exhibited the aluminum byproduct deposition which coated materials within the test enclosure.

The current model for segmented (non-segregated) bus duct fires found in NUREG/CR-6850 Supplement 1 largely attributes the damage potential of bus duct HEAF’s to the ejected molten metal from the bottom of the bus duct. This guidance was based on results of actual bus duct HEAF investigations. Specifically, one well-documented event considered typical of a bus duct fire occurred at Diablo Canyon on May 15, 2000.[4] In this Diablo Canyon event, the damage profile was oriented vertically down from the arc location. Subsequently, NUREG/CR-6850 Supplement 1 used this characteristic to model the ZOI in a conical shape from the point of origin. Test 26 provides evidence that the current model may be insufficient for estimating the damage potential for bus duct HEAF events involving aluminum components in both the extent and orientation of expected damage.

[4] U.S. NRC Information Notice (IN) 2000-14, “Non-Vital Bus Fault Leads to Fire and Loss of Offsite Power,” September 27, 2000, and U.S. NRC Diablo Canyon Inspection Report No. 50-275/00-09; 50-323/00-09, July 31, 2000.

Testing Conclusion

The physical damage to the test specimens, measurement devices, and the testing facility observed during tests Test 23 (IP-20 Switchgear) and Test 26 (Bus Duct) was attributed to the presence of aluminum. The presence of aluminum in the components, subcomponents, or parts that form part of the normal current carrying pathway caused a more energetic plasma development when consumed during the arcing process. This more energetic plasma under these test conditions caused a larger amount of cabinet damage and the transport of gaseous high energy particles/plasma farther than previously assumed. These two tests that included aluminum components yielded results that significantly exceeded the expected ZOI postulated in accordance with the guidance currently in use in NUREG/CR-6850 and NUREG/CR-6850 Supplement 1. Also staff observed in both tests involving aluminum a previously unidentified potential failure mechanism; e.g., a significant layer of aluminum combustion byproducts plated out on all surfaces within the test cell, significantly affecting electrical equipment. This conductive aluminum combustion byproduct layer caused major electrical problems with the test facility power supplies and required an extensive repair and cleanup activity to correct. The extent of damage observed from Test 23 and Test 26, which contained aluminum components, far exceeded the damage observed from other tests which did not contain aluminum components.

The NRC staff is still investigating the exact manner in which the presence of aluminum increases the resultant energy released during a HEAF and the subsequent increase in the area of the ZOI.

6. Regulatory Approaches for Fire Protection

The NRC regulations require licensees to maintain a fire protection program at every commercially operating U.S. nuclear power plant to ensure the facilities operate safely. Plants can choose between two approaches: deterministic or performance-based. Therefore, HEAF events are analyzed differently depending on the regulatory framework of the individual plant.

Regardless of approach, all fire protection programs employ the design concept of defense-in-depth. Fire protection programs at nuclear power plants use the concept of defense-in-depth to achieve the required degree of reactor safety. This concept entails the use of three echelons of safety to achieve the following objectives:

1. Preventing fires from starting.

   The presence of aluminum does not change the first echelon of defense. The initiation of HEAF events is independent of the presence of aluminum.

2. Rapidly detecting, controlling, and extinguishing fires that do occur.

   The presence of aluminum may impact the second echelon of defense. The aluminum present could act as a fuel and become a source for a higher heat release rate and smoke production, resulting in a very difficult fire to locate and extinguish. The remaining secondary fires (those non-aluminum components and secondary fuels ignited by the HEAF, such as cable trays) will respond to fire-fighting efforts in the same way as non-aluminum HEAFs.

3. Providing an adequate level of protection for structures, systems, and components important to safety, so that a fire that is not promptly extinguished will not prevent a safe shutdown of the plant.

   The presence of aluminum may impact the third echelon of defense since a performance-based analytical process is used to demonstrate acceptable risk for those fires that do occur. Any performance-based analyses performed using the baseline model that involved HEAF scenarios involving aluminum components may also underestimate the risk. Additionally, deterministic requirements based on prescriptive separation criteria could be challenged with an increased damage zone from HEAF events involving aluminum.

Deterministic Basis—10 CFR 50.48(a), 10 CFR 50.48(b)

Approximately half the nuclear fleet is licensed using deterministic requirements to demonstrate conformance with fire protection regulations that are in 10 CFR Part 50, Appendix A; “General Design Criteria for Nuclear Power Plants”; 10 CFR Part 50, Appendix R, “Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979”; 10 CFR 50.48(a), and 10 CFR 50.48(b). In particular, 10 CFR Part 50, Appendix R, Section III.G.2 states;

> …where cables or equipment of redundant trains of systems necessary to achieve and maintain hot shutdown conditions are located within the same fire area outside of primary containment, one of the following means of ensuring that one of the redundant trains is free of fire damage shall be provided: … (b) Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet with no intervening combustible or fire hazards. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area.

In addition, NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” also addresses the use of physical separation requirements to ensure independence is not compromised. NUREG-0800 refers to IEEE Std. 384-1992, “Standard Criteria for Independence of Class 1E Equipment and Circuits,” as endorsed by Regulatory Guide 1.75, "Criteria for Independence of Electrical Safety Systems," for the acceptance criteria for the separation of circuits and electrical equipment.

The regulations require that one train of systems necessary to achieve and maintain hot shutdown shall be free of fire damage. The regulation prescribes several methods of ensuring safe shutdown, including train separation (20 ft.) free of intervening combustibles, fire barriers, and a combination of detection and suppression with no intervening combustibles. In cases where these requirements were not practical, or there was a more favorable approach to achieving an equivalent level of safety, applicants and licensees proposed alternatives, typically through specific exemptions, deviations, and/or license amendments. The intent of these requirements is to provide sufficient physical separation between redundant safe shutdown trains.

Based upon results in recent testing, a HEAF event that involves aluminum may result in a ZOI that is larger than the 6.1 m (20 ft.) minimum separation requirement for redundant trains. The larger ZOI has the potential to cause damage to both success paths for a given safe shutdown function, irrespective of the presence of the suppression system, thereby, impacting the ability to safely shutdown and cool down the plant. Those licensees who proposed alternative methods to achieve the necessary train separation may also be impacted by the increased ZOI. Additionally, a HEAF involving aluminum introduces a new failure mode; the potential spread of conductive byproduct onto sensitive electrical equipment may cause additional failures.

Risk Informed, Performance Based - 10 CFR 50.48(c)

In 2004, the NRC modified the fire protection regulations in 10 CFR 50.48(c) to allow licensees to adopt, on a voluntary basis, National Fire Protection Association (NFPA) Standard 805, "Performance-Based Standard for Fire Protection for Light-Water Reactor Electric Generating Plants," in lieu of their existing fire protection licensing basis. This approach offers plants the opportunity to use risk-information and performance-based tools to develop a comprehensive fire protection program which provides an adequate level of protection from fires.

Nuclear power plants that are licensed under 10 CFR 50.48(c) are required to use methods acceptable to the NRC staff when developing their fire PRAs. NFPA 805 licensees are also required to maintain their fire PRA consistent with the as-built, as-operated, and maintained plant, and incorporate applicable operating experience. Licensees are also required to maintain configuration management of the supporting fire PRA analyses through a maintenance, update, and upgrade process. As of May 2017, 25 sites (with a total of 39 units) have transitioned to a risk-informed, performance-based, fire protection program. An additional two plants (with three units) are currently under review by the NRC staff.

The current acceptable methodology in NUREG/CR-6850 and its Supplement 1, "Fire Probabilistic Risk Assessment Methods Enhancements," provide a method to determine and model the hazards from HEAF events within the fire areas. All plants that have either already transitioned or are in the process of transitioning to NFPA 805 use this current methodology in NUREG/CR-6850. HEAF scenarios are included in some of the high-risk scenarios contributing to total fire risk, which have been documented in NFPA 805 license amendment requests (LARs). The HEAF scenarios are included in the engineering analyses of the fire risk evaluation to demonstrate where variances from the deterministic requirements (VFDRs) of NFPA 805 are acceptable from a risk, defense-in-depth, and safety margin standpoint, using a performance-based approach. Each plant has also evaluated VFDR’s and shown them to be acceptable.

For those plants approved in accordance with 10 CFR 50.48(c), this issue is limited in scope to switchgear, bus ducts, and other current-carrying electrical equipment and associated targets that have been analyzed for HEAFs in risk-informed/performance-based (RI/PB) fire protection programs using the currently accepted methods presented in NUREG/CR-6850 and NFPA 805. The potential impacts to these structures and components is that the risk analysis and any VFDR delta risk evaluations performed during the transition to the RI/PB fire protection programs may be non-conservative, thereby underestimating the risk contribution from HEAFs involving equipment containing aluminum components. If the ZOI from a HEAF involving aluminum significantly increases, relative to the current licensing basis, subsequent evaluations may be required to support future voluntary risk-informed licensee submittals.

In addition to the aluminum impact to the modeling strategy, various mitigation techniques have been proposed as part of the transition to NFPA 805 (e.g., “HEAF shields”). HEAF shields are intended to mitigate extent of damage, thereby reducing the risk of a particular scenario. Based upon the potential for an increased damage state from the influence of aluminum on a HEAF, licensees may need to reevaluate associated design assumptions and qualifications.

Once an accepted method has been developed and communicated to licensees, licensees are expected to evaluate the impact of that method on their analyses consistent with their PRA configuration control program. For those plants that have transitioned to a performance-based fire protection program under 10 CFR 50.48(c) and NFPA 805, any non-conservatisms discovered as a result of this HEAF issue involving aluminum would mean that the current baseline risk model at plants that have aluminum components may underestimate the risk.

7. Risk Significance

For many plants in this country, internal fire risk is a dominant risk contributor. The staff found that HEAF-initiated scenarios have the potential to contribute significantly to fire risk at some plants (based upon the NFPA 805 plants who provided sufficiently detailed risk information on a scenario/ignition source level). From a sample of ten NFPA 805 plants, the range of fire risk contributed by HEAF initiated fire scenarios ranged from 1 percent to 27 percent.[5] The staff estimated the average per unit risk contribution was approximately 15 percent from these corresponding plants. The staff finds that HEAF events involving aluminum could potentially increase the plant CDF for some scenarios. This risk increase is caused by increasing the ZOI for HEAF scenarios involving aluminum. However, this risk increase, like fire in general, is highly scenario dependent and driven by room configuration.

Operational experience shows that HEAFs continue to occur, despite the extensive electrical protection against such fire-initiated scenarios built into the design of plants. An in-depth evaluation of operational experience shows that significant complications to shutting down the plant can occur during and after a HEAF. Like most major fire events, HEAF events normally generate large quantities of dense smoke, cause significant equipment damage, and in many cases, challenge operators with scenarios unlikely to have been trained on. These conditions contribute to the likelihood of human errors, which can greatly complicate the plant response to these events. Also, some plants were designed with multiple divisions in some common fire areas (e.g., the cable spreading room, the switchgear room, and turbine building). Given the range of configurations of equipment and cabling found at plants, configurations could exist where an enlarged ZOI model could result in loss of redundant or diverse equipment during a HEAF event. Consequently, serious fire events, like HEAF events, may produce failures of redundant trains leading operators to rely upon using remote operating panels for shutdown operations, or produce failures that may lead to other risk significant conditions.

After a review of recent HEAF testing and operating experience, the staff has also identified a new potential failure mode (e.g., the spread of electrically conductive aluminum byproducts in HEAF events involving aluminum). This byproduct has the potential to damage sensitive electronics beyond the ZOI.

The staff concludes that HEAF events involving aluminum could be a larger contributor to internal fire risk for some plants compared to HEAF events without aluminum. This conclusion is based on risk-insights from NFPA 805 LARs and operational experience which shows the continual occurrence and importance of HEAF events. The impact of an expanded HEAF ZOI from the involvement of aluminum has the potential to damage additional equipment. Based on qualitative risk estimates, the staff contends that the risk of a HEAF involving aluminum could

---

5 The staff extracted the range of HEAF-initiated CDF from the original NFPA 805 LARs; the CDFs were not updated following the staff's LAR review. Nonetheless, the staff, by citing this CDF range, concludes that HEAF is an important contributor to risk for some nuclear power plants.

potentially increase the plant's core damage frequency (CDF) for some fire scenarios, based on a larger ZOI.