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SUBJECT: HIGH ENERGY ARCING FAULTS LIC-504 TEAM RECOMMENDATIONS

I. Summary

In accordance with the Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-504, "Integrated Risk-Informed Decisionmaking Process for Emergent Issues," Revision 5 (ADAMS Accession No. ML19253D401), the U.S. Nuclear Regulatory Commission (NRC) staff examined the potential change in the estimated fire risk associated with high-energy arcing faults (HEAF) based on recent operating experience and testing to develop recommendations for your consideration. The estimated change in risk due to HEAF fires is associated with the application of the new HEAF Probabilistic Risk Assessment (PRA) methodology developed by NRC's Office of Regulatory Research (RES) in collaboration with the Electrical Power Research Institute (EPRI), in comparison to the estimated risk using the guidance documented in Appendix M of NUREG/CR-6850 entitled, "EPRI/NRC-RES Fire Probabilistic Risk Analyses (PRA) Methodology for Nuclear Power Facilities" and its Supplement 1.

The NRC staff used the best available information to conduct the LIC-504 analysis. To help assure that the analysis was reflective of operating light water reactors (LWRs) in the United States (US), the NRC staff secured the support of two reference nuclear power plants in order to obtain plant-specific information and insights to improve the realism of the analysis and the usefulness of the insights. In addition, the staff reviewed HEAF events that occurred at U.S.

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LWRs as well as a compilation of events at plants operating outside of the U.S., documented in a report prepared by the Nuclear Energy Agency (NEA/CSNI/R(2013)). To supplement risk-insights derived from the analyses and the reference plants, the staff used information derived from the NRC's accident sequence precursor (ASP) database for HEAF events.

This memorandum presents the LIC-504 team's detailed analyses and recommendations for management's consideration regarding potential follow-up actions by NRC staff. The staff considered and investigated a full range of potential options that it could recommend under the NRC's licensing, rulemaking, and oversight responsibilities. The staff noted some increases as well as some decreases in risk when the new HEAF methodology was applied; however, based on the results of the overall staff's assessments, the staff has concluded that there is no significant increase in total HEAF risk, warranting the need for any additional regulatory requirements. In addition, the staff evaluated various communication options that would enable the staff to share its insights with external stakeholders for licensee consideration to implement effective steps to further reduce and/or mitigate HEAF risks.

II. Background

Safety issues that emerge as a result of U.S. or international operating experience or NRC's inspection activities, may give rise to the potential for plant-specific or generic implications for the industry. The objective of the LIC-504 review process is to identify, as needed, risk-informed options (e.g., issuing orders to shut down plants or impose interim compensatory measures, issuing generic communications, revising inspection procedures, etc.) to address any such emerging issues in a timely manner and document the bases of those decisions. In identifying risk-informed options in accordance with LIC- 504, the staff considers the potential impact of the emerging issue in compliance with the regulations, defense-in-depth, and safety margins for the facility, magnitude of the potential risk increase, and other matters important to the NRC, such as enterprise risk.

The LIC-504 analysis uses a two-step process that could result in one of four different scenarios:

1. Taking prompt regulatory action, such as issuing an order to shut down the affected unit(s) or provide compensatory measures at the site where the concern is identified
2. Taking prompt regulatory action for other operating nuclear power plants (i.e., if a generic concern exists), such as issuing shutdown orders or ordering compensatory measures
3. Developing risk-informed options to resolve the issue at the unit or site where the concern is identified
4. Developing risk-informed options to resolve the issue at other potentially affected units, as appropriate

Because the HEAF LIC-504 analysis focused on evaluating the risk significance of the issue and dispositioning any significant increase in accordance with the LIC-504 guidance, the staff took a reference plant approach and did not perform unit- or site-specific analysis. An explanation of the reference plant approach is provided in Section IV, below.

The NRC completed the first step of the LIC-504 evaluation, whereby the staff assessed whether there was a need for immediate regulatory action(s) and concluded that U.S. plants remain safe without the agency taking any prompt regulatory action(s). The staff documented

the basis for that conclusion in the memorandum, "Prompt Safety Concern Determination Regarding Aluminum Enhanced High Energy Arcing Faults," dated October 5, 2021 (ADAMS ML21272A262). This conclusion was based on the staff's insights from a qualitative risk evaluation that considered safety margins and defense-in-depth features associated with fire protection programs and applicable operating experience at U.S. nuclear power plants. This memorandum documents the results of the second and final step of the evaluation, which involved a more detailed risk evaluation, and identified specific recommendations.

III. Issue Description

Issued in 2005 and supplemented in 2010, the NRC documents its guidance for modeling HEAF events in fire PRA in Appendix M of NUREG/CR-6850 and its Supplement 1." This guidance postulates that HEAFs can occur in switchgear (SWGR), load centers, and bus ducts with a nominal voltage of 440 volts (V) or greater and defines a zone of influence (ZOI) within which targets are assumed to be damaged. For the purposes of a fire PRA, a damaged target is assumed to be functionally failed.

Because the PRA methods for HEAF, as described in NUREG/CR-6850, were formulated based on limited observational data, the NRC conducted an international experimental campaign from 2014 to 2016 to validate these methods. The results of these experiments uncovered the potential for an unexpected hazard posed by aluminum components in or near electrical equipment and the potential for unanalyzed equipment failures, which the current PRA modeling guidance may not accurately address. As a result, on March 4, 2016, RES, based upon a request from the NRC's Office of Nuclear Reactor Regulation, entered this issue into the Generic Issues Program in accordance with Management Directive 6.4, "Generic Issues Process." As additional information was developed during the staff's assessment of the potential generic issue, it was later determined that the LIC-504 process provided a more appropriate process to resolve the HEAF concern. As such, RES issued a memorandum (ML21237A360) to remove the HEAF issue from the Generic Issues Program and leverage the LIC-504 process to determine whether there was a significant increase in risk that warranted any additional regulatory actions.

As the staff gained additional insights from the HEAF experiments and fire modeling, the staff determined that copper and aluminum HEAF ZOIs should be treated in the same manner based on the current state of knowledge. While there are apparent differences in the chemical energy released depending on material properties, the current data sets do not support a statistically significant difference in the resulting ZOI based on material properties alone. The staff also determined that, in some cases, the HEAF ZOIs associated with the switchgear could be larger or smaller than those estimated using NUREG/CR-6850 methods, depending on the specific circumstances. The staff further concluded that for some HEAF scenarios associated with non-isophase busducts, ZOIs could be substantially greater than those predicted by the current NUREG/CR-6850 guidance. The cases of substantially larger HEAF ZOIs for non-isophase bus ducts constituted a concern because damage to additional structures, systems, and components located outside the HEAF ZOIs as estimated by NUREG/CR-6850, may not have been appropriately included in the fire PRA models and by implication in plant analyses. This issue could impact a number of licensees who have adopted risk-informed initiatives, that require the use of fire PRA models (e.g., Title 10 of the *Code of Federal Regulations* (10 CFR) 50.48(c), National Fire Protection Association 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," Risk-Informed Technical Specification 4b), as these fire PRA models must be maintained in accordance with regulatory requirements and imposed license conditions.

The current HEAF PRA modeling methodology documented in NUREG/CR-6850 was first published in 2005 and addresses HEAF from switchgear. That method was based primarily on the evaluation of several HEAF events. Supplement 1 to NUREG/CR-6850 was published in 2010 and addresses HEAF from bus ducts. Since the publication of these HEAF methods, the NRC staff, in collaboration with EPRI, has updated the HEAF PRA methodology using more recent operating experience, testing, and other enhancements to fire modeling. Some of the key advances to the new HEAF PRA methodology include the following:

- Changes to HEAF frequencies and non-suppression failure probabilities
- Substantial changes to ZOIs for non-isophase bus ducts and for low and medium voltage switchgear
- Crediting Electrical Raceway Fire Barriers Systems (ERFBS) in the HEAF ZOI as a means of preventing damage from HEAF effects
- The ability to evaluate additional damage that may occur due to longer fault clearing times

Therefore, even though the staff concluded that the best available information could not support distinguishing between aluminum versus copper ZOIs, the NRC staff identified several major improvements to HEAF PRA modeling. The LIC-504 assessment was then focused on examining whether there was a significant increase in risk due to HEAFs by comparing the change in HEAF risks associated with the use of the existing HEAF PRA methodology in NUREG/CR-6850 and Supplement 1 to the new HEAF PRA methodology, a draft of which is expected to be published for public comment by the end of July 2022.

IV. Summary of Quantitative Risk Analysis and Insights

This section summarizes the approach, results, and key risk insights associated with the quantitative risk analyses performed by the NRC staff using the information provided for two reference plants. Enclosure 1 gives the details of this analysis such as associated assumptions, uncertainties, and limitations.

The staff secured the support of two licensees and selected two reference plants, including a Boiling Water Reactor 4 with a Mark I containment and a 3-loop Pressurized Water Reactor with a large dry containment, to investigate the differences in risk between the current HEAF PRA methodology and the new HEAF PRA methodology. The staff chose the two reference plants based on the following:

- The availability of an independent NRC-developed Standardized Plant Analysis Risk model that includes fire risk
- The willingness of the licensee to support the staff’s activities associated with its evaluation to determine whether there is a significant change in risk associated with the use of the new PRA HEAF methodology
- The difference in general plant configuration for fire risk between the two reference plants

The staff’s sole intention in securing the collaboration with the licensees of the two reference plants was to develop risk estimates and risk insights using the best available information. Analyses of the reference plants were performed using the new fire PRA HEAF methodology, and additional sensitivity studies were performed to represent plants from the broader nuclear

industry. The sensitivity studies were based on more challenging configurations and larger ZOIs than the reference plants in order to extend the applicability of its analyses. The staff noted that there was some variation in how each reference plant addressed HEAF modeling. For example, one reference plant credited FLEX strategies (diverse and flexible coping strategies) in the HEAF PRA information. The other reference plant did not. The reference plants also used different PRA methods and levels of refinement to develop the HEAF risk. The staff attributes this latter difference primarily to the different reference plant philosophies for evaluating fire risk; one reference plant exercised its model extensively to refine its fire risk, while the other plant concluded that a simpler level of detail was adequate.

The staff leveraged insights derived from the reference plant HEAF PRA analyses to support the quantitative analysis. For example, the dominant sequences of the fire PRA HEAF scenarios were a key input that the staff used to select the areas for the plant walkdowns.
Although one criterion used by the staff in selecting reference plants was the availability of fire PRA information in the NRC's PRA models, the staff used the conditional core damage probabilities and conditional large early release probabilities computed by the reference plants using their fire PRA models, instead. Plant walkdowns enabled the staff to determine how HEAF scenarios and associated frequencies could be modified to capture the changes related to the new HEAF fire PRA methodology. For example, the walkdowns were instrumental in identifying additional targets that would be impacted by the bus duct HEAF scenarios, as a result of the larger ZOIs associated with the new HEAF PRA methodology. The walkdowns also enabled the staff to eliminate some scenario targets in the HEAF ZOIs, if they were protected by ERFBS, that were failed according to the current NUREG/CR-6850 guidance.

Table 1 below summarizes the results for the two reference plants' base HEAF related risks using current NUREG/CR-6850 guidance versus the new HEAF methodology. The units of all numbers provided in Tables 1-5 are events per year.

Table 1: Comparison of Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) Using Current Versus New HEAF PRA Guidance

Description	CDF (new method)	CDF (NUREG\CR-6850)	ΔCDF	LERF (new method)	LERF (NUREG/ CR-6850)	ΔLERF
Reference Plant 1						
SWGR related	1.7E-6	1.3E-5	-1.1E-5	3.9E-8	3.5E-7	-3.2E-7
Bus Duct related	5.0E-7	4.6E-7	4.5E-8	3.6E-8	1.5E-8	2.0E-8
Total HEAF risk	**2.2E-6**	**1.4E-5**	**-1.1E-5**	**7.5E-8**	**3.7E-8**	**-3.0E-7**
Reference Plant 2						
SWGR related	8.7E-7	3.7E-7	5.0E-7	2.2E-8	1.2E-8	9.2E-9
Bus duct related	3.3E-5	1.4E-7	3.3E-5	3.7E-6	7.4E-9	3.7E-06
Total HEAF risk	**3.4E-5**	**5.1E-7**	**3.4E-5**	**3.7E-6**	**1.9E-8**	**3.7E-6**

For Reference Plant No. 1, the reduction in HEAF risk associated with the new method was largely driven by the reduction in switchgear related HEAF risks. The ability of the new method to credit protection from HEAF afforded by the ERFBS and the relatively small arc duration

time (which in turn reduces the energy released from the HEAFs and, consequently reduces the ZOIs) contributed to this reduction. For Reference Plant No. 2, the increase in HEAF risk is dominated by the estimated risk increases associated with the bus ducts due to increased risk of ZOIs, and potential for additional targets.

To further refine the staff's perspective on the risk significance, as it may apply to other plants whose configurations and characteristics could be different, several sensitivity studies were also performed. Enclosure 1 contains details on the various parameters modified to perform the sensitivity studies.

For the sensitivity study on Reference Plant No. 1, the ZOI and configuration of the switchgear rooms were adjusted. For example, the ZOI was extended for the first switchgear bank to damage a conduit containing a critical target located outside the ZOI for the reference plant. For the second switchgear bank, a conduit containing a critical target, which terminated in the end cabinet in the reference plant was assumed to run along the full length of the cabinets. Finally, a cable tray containing critical targets running in front of the third switchgear bank and just outside the damaged zone for each single cabinet was assumed to be damaged by the fire developed by the HEAF in each cabinet. Fire modeling sensitivities were also performed for a large fault clearing time, which led to multiple, simultaneous cabinet fires. Table 2 summarizes the results of these sensitivities.

Table 2: Summary of Results of Sensitivity Studies for Switchgear for Reference Plant No. 1

Description	CDF for SWGR only (new method)	CDF for SWGR only (NUREG\CR-6850)	ΔCDF	LERF for SWGR only (new method)	LERF for SWGR only (NUREG\CR-6850)	ΔLERF
No changes	1.7E-06	1.3E-05	-1.1E-05	3.9E-08	3.5E-07	-3.2E-07
Changed ZOI and the plant configuration to include additional targets	2.5E-06	1.3E-05	-1.0E-05	4.9E-08	3.5E-07	-3.1E-07
Changed fire modeling to reflect increased fault clearing times	1.7E-06	1.3E-05	-1.1E-05	3.9E-08	3.5E-07	-3.2E-07
Changed ZOIs, plant configuration, and fire modeling	2.5E-06	1.3E-05	-1.0E-05	4.9E-08	3.5E-07	-3.1E-07

For Reference Plant No.2, the staff performed a sensitivity study to investigate the impact of HEAF protective structures on risk. The risk values for this sensitivity study in Table 3 represent the risk only from the switchgear cabinets, which had HEAF-protective structures above them. Because the results for Reference Plant No. 2 were developed from a larger number of HEAF fire scenarios than the sensitivity study results (which relied only on those switchgear cabinets with HEAF protective structures), the core damage frequency (CDF) and large early release frequency (LERF) for the reference plant cannot be directly compared with the sensitivity study. However, the ΔCDF and ΔLERF between the two cases can be compared. As shown in Table 3, that sensitivity study demonstrated

that protecting important cables from fire damage is important to reducing risk from HEAFs, just as it is for fire PRA, in general.

Table 3: Sensitivity Study Results for Switchgear HEAF Reference Plant No. 2

Description	CDF for SWGR only (New Method)	CDF for SWGR only (NUREG\CR-6850)	DCDF	LERF for SWGR only (New Method)	LERF for SWGR only (NUREG\CR-6850)	DLERF
No changes	8.7E-07	3.7E-07	5.0E-07	2.2E-08	1.2E-08	9.2E-09
Changed by removing credit for all HEAF-protective structures (CDF/LERF based only on the subset of switchgear associated with protective structures)	1.1E-05	3.5E-09	1.1E-05	3.0E-07	2.3E-10	3.0E-07

For Reference Plant No. 1, the staff performed a sensitivity study using the maximum value of 5 feet for some scenarios and using the new method for busducts for the 4kV and the 13kV switchgear rooms. The ZOI was increased to accommodate the fact that other plants may have larger fault clearing times and more targets in the vicinity of bus ducts. The increased ZOI resulted in an increased number of damaged targets for the bus duct scenarios and, consequently, an increased CDF. Table 4 summarizes the results of that sensitivity study.

Table 4: Sensitivity Study Results for Bus Ducts for Reference Plant No. 1

Description	CDF for busducts (New Method)	CDF for busducts only (NUREG\CR-6850 Supplement 1)	ΔCDF	LERF for busducts only (New Method)	LERF for busducts only (NUREG\CR-6850 Supplement 1)	ΔLERF
Reference Plant #1	5.0E-07	4.6E-07	4.5E-08	3.6E-08	1.5E-08	2.0E-08
Sensitivity Study – changes to ZOI	9.4E-06	4.6E-07	8.9E-06	1.7E-07	1.5E-08	1.5E-07

No sensitivity studies were performed for the bus ducts at Reference Plant No. 2, because it had larger fault clearing times, resulting in the use of ZOIs on the larger end, as described in the new HEAF PRA methodology. Thus, Table 5 only shows results for Reference Plant No. 2. The second row of Table 5 is the staff's estimate of the total change in HEAF risk for Reference Plant No. 2 developed using the new methodology. The second row was derived from applying multiplicative factors to certain fire scenarios, as described in Enclosure 1, to fully account for propagating failures of components downstream from bus ducts in the reference plant's PRA. Row 1 shows the staff's evaluation of risk from only the walked down bus ducts and was extrapolated using the multiplicative factors on a scenario basis to lead to the full risk results in the second row. Thus, the full risk described in the second row is larger than the risk in the first row from only the walked down bus ducts.

Table 5: Results for Bus Ducts for Reference Plant No. 2

Description	CDF for busducts (New Method)	CDF for busducts only (NUREG\CR -6850 Supplement 1)	∆CDF	LERF for busducts only (New Method)	LERF for busducts only (NUREG\CR -6850 Supplement 1)	∆LERF
Reference Plant No. 2 (-walked down scenarios only)	2.0E-05	5.5E-09	2.0E-5	1.0E-06	2.8E-10	1.0E-06
Reference Plant No. 2 (All scenarios, including multiplicative factors)	3.3E-05	1.4E-07	3.3E-05	3.7E-06	7.4E-09	3.7E-06

Treatment of Uncertainties

The staff used the best available information in the risk assessment for the reference plants and sensitivity studies. Therefore, the staff relied upon the PRA models owned and maintained by the reference plants for the conditional core damage probabilities and conditional large early release probabilities. The staff performed both direct and indirect checks of these values, as discussed in Enclosure 1. The staff walked down configurations of interest at the reference plants, and collected additional targets as warranted by the new ZOIs, rather than relying solely on drawings. The staff is aware that various parameters in the PRA have uncertainties, and in this vein, has confirmed that the HEAF sources generally expected as important, showed up to be important in the ranking of fire sources in the HEAF PRA.

The staff did not perform any quantitative uncertainty analyses in support of the LIC-504 study. Rather, the staff performed sensitivity studies using the results from the reference plants to gain insights on how the results from the reference plants may apply to the broader industry. For example, the staff used different values for critical parameters such as the fault clearing times, which would lead to larger ZOIs and challenge fire risk. In the reference plant analyses, bus ducts demonstrated a higher change in risk than for switchgear, consistent with the larger impact the new method had on the ZOI for bus ducts compared to switchgear.

Conclusions from the Quantifications Using Reference Plant HEAF Risks

The staff gained the following key risk-informed insights on fire related HEAF risks, based on the analyses conducted using the information from the reference plants:

- Application of the new methodology for bus duct HEAFs provided a significant increase in estimated risk in many cases, but not all. For example, a significant change was not found for Reference Plant No.1 bus ducts. However, sensitivity studies using Reference Plant No. 1 and the reference plant study for Reference Plant No. 2, generally showed a significant increase in risk. The instances that showed significant increases in risk were attributed to larger ZOIs associated with the new HEAF PRA methodology. The major difference between the new HEAF PRA methodology and the existing NUREG/CR-6850 Supplement 1 methodology is the assignment of larger ZOIs for long fault duration times. Thus, the staff concludes that those plants with relatively long fault clearing times, and consequently larger ZOIs for bus ducts, could experience a significant increase in risk due to HEAFs.

- Application of the new methodology for switchgear HEAFs showed an increase in estimated risk for certain circumstances. The change in risk from Reference Plant No. 2 is larger than that for Reference Plant No. 1. However, the staff performed a simplified analysis for Reference Plant No. 2 relative to Reference Plant No. 1. Furthermore, the vertical ZOI above the switchgear for the new HEAF PRA methodology is always smaller than the value from NUREG/CR-6850. Additionally, the new methodology predicts fire damage from HEAF in a region near the cabinet (just above and in front of) not covered by NUREG/CR-6850. For plant configurations with additional targets in this region, the switchgear could see a significant increase in risk with the new PRA HEAF methodology. Additionally, in a few cases the ZOI other than the vertical ZOI increased in the new methodology. Finally, longer fault clearing times lead to multiple, simultaneous switchgear HEAF fires, which may expose additional cables to fire damage.

- The new HEAF PRA methodology credits ERFBS from preventing damage to cables within the new ZOI of bus ducts and switchgear, unlike NUREG/CR-6850 and its Supplement 1. The staff noted that the risk decrease for the switchgear in Reference Plant No. 1 was primarily attributed to the credit given for ERFBS in the new methodology. Depending on the plant-specific configurations, fault clearing times, and risk profiles, application of the new methodology, including credit for ERFBS, may result in an estimated risk reduction.

- The changes in risk from the application of the new method in Reference Plant No. 2, including the sensitivities, were generally larger than those for Reference Plant No. 1. Reference Plant No. 2 had rooms with larger amounts of cabling that were therefore more sensitive to effects from HEAFs. HEAF risk, as in general for fire risk, is configuration dependent. As demonstrated by the sensitivities from Reference Plant No. 2 for the switchgear, protecting important cabling from fire damage is important to Mitigate fire risk.

V. Summary of Risk Insights Based on Operating Experience Including Accident Sequence Precursors

One of the main objectives of a PRA is to gain insights about a facility's response to initiating events and accident progression, including the expected interactions among facility structures, systems, and components, and the operating staff. Risk-informed insights are derived by investigating, in a systematic manner: (1) what can go wrong, (2) how likely it is, and (3) what are the consequences. Risk-informed insights can be obtained through both quantitative and qualitative investigations. Quantitative risk results from PRA calculations are useful, but they are generally supplemented by qualitative risk insights and traditional engineering analysis. Qualitative risk insights include generic results (i.e., results that have been compiled from numerous PRAs that have been performed in the past) and from operating experience that are applicable to a group of similar plants. Risk-informed insights are an important part of risk-informed regulation, in which regulatory decisions are made by integrating risk insights with considerations of defense-in-depth and safety margins.

In addition to quantitative analyses, the NRC staff reviewed the following documents to obtain qualitative risk insights relating to HEAFs.

- Nine HEAF events from the NRC's Accident Sequence Precursor (ASP) Database (References to each of these events are provided in Enclosure 2.)
- NRC report entitled "Operating Experience Assessment: Energetic Faults in 4.16 kV to 13.8 kV Switchgear and Bus Ducts That Caused Fires in Nuclear Power Plants 1986–2001," February 2002 (ADAMS ML021290364.)
- HEAF events described in the Organisation for Economic Co-operation and Development (OECD) report entitled "Fire Protection Topical Report No. 1, Analysis of High Energy Arcing Faults," June 2013.
- Six HEAF events discussed in NRC Information Notice (IN) 2017-04, "High Energy Arcing Faults in Electrical Equipment Containing Aluminum Component," August 2017, (ADAMS ML17058A343.)
- Electric Power Research Institute (EPRI) Report No. 3002015459 entitled, "Critical Maintenance Insights on Preventing HEAF," March 2019. (Available at no cost from the EPRI website.)
- Information gathered from the two reference plants.

Each of the events reviewed by the staff provided one or more insights relating to measures that could minimize the likelihood of HEAFs or mitigate the consequences if a HEAF were to occur. The objective of conducting this study was to communicate risk-informed insights consistent with the "teaching" element of the NRC's *Be RiskSMART* framework.

Enclosure 2 contains details about the analysis that the staff conducted using the information gathered from the sources listed above. The list below provides the risk-informed insights gathered from that analysis.

Risk-Informed Insights Generated Using the NRC's ASP Database

- In general, HEAFs leading to station blackouts (SBOs) constitute the highest HEAF related risks. Plant design and operational changes that have been adopted to enhance the mitigation of beyond design basis accidents rule (10 CFR 50.155 "Mitigation of beyond-design-basis events") are likely to reduce HEAF related risks.

- HEAFs that can lead to SBOs are likely to initiate at buses or switchgear that are essential to supply alternating current power from both offsite power and emergency diesels (or other emergency supply). Resources focused to minimize the likelihood of HEAF occurrence at those switchgear and buses (e.g., improved preventive and predictive electrical maintenance) can reduce HEAF related risks. Measures taken to minimize the possibility of a HEAF at one emergency bus causing failure of the redundant electrical train due to consequential failures (e.g., due to smoke, or design deficiencies), will also minimize the SBO related HEAF risks.

Risk-Informed Insights from EPRI Report No. 3002015459

- With respect to circuit breakers, the report noted that maintenance of the Unit Auxiliary Transformer breakers is particularly important because its failure can lead to an extended duration generator-fed fault at the first switchgear bus. Operating experience has shown that this breaker is more likely to fail during automatic bus transfers. The report acknowledged the challenges that licensees confront in performing preventive maintenance due to constraints associated with outage schedules and offered risk-

informed guidance, so that licensees may focus their maintenance on the risk critical subset of maintenance activities.

- With respect to switchgear, the report noted that for critical switchgear, such as feeder circuit breakers that carry higher currents, and switchgear that is part of a bus transfer scheme, proper maintenance of connections on both the bus side and the circuit breaker side is especially important.

Risk-Informed Insights Generated Using HEAF Scenarios of Reference Plants

- HEAF scenarios generated by licensees using their fire PRA models may enable them to identify the subset of plant components whose design and maintenance dominate the HEAF related risks. This information may allow licensees to minimize HEAF risks by focusing resources (e.g., preventive maintenance) on that subset of components.

- Based on the U.S. operating history with HEAF since 2010, HEAF events that constitute accident sequence precursors are likely to occur once in every 2 years, i.e., based on the ASP database, HEAF events represent an average risk (CDF) of about $5x10^{-6}$/year for each operating unit. The estimated HEAF related CDF using the new HEAF methodology at the two reference plants were $2x10^{-6}$/year and $3.3x10^{-5}$/year, respectively.

Risk-Informed Insights Generated from the Staff review of HEAF Events Documented in the OECD Report

- Frequently, HEAF events, even those that are not initially risk significant, can cause subsequent failures due to explosion effects, smoke, and ionized gases. These subsequent failures can create a chain of consequential events that can pose special challenges to operators. Furthermore, some HEAF events involve operator errors that further contribute to the risk significance of the event. These subsequent failures often involve complex interactions among the operators, fire phenomenology, and mitigation capability, and can be extremely challenging to predict. Due to these factors, it is impossible to predict and mitigate all consequences of a HEAF; so, a focus on preventing HEAF events remains an important aspect of balancing HEAF risk management.

VI. Recommendations

Enclosure 3 contains the staff's evaluations and conclusions, using Table C-1 of LIC-504 as a template. The NRC staff used insights obtained from the quantitative analysis (Enclosure 1) and qualitative analysis (Enclosure 2) to examine whether any regulatory actions are needed, commensurate with the risk significance of the issue. The staff considered and investigated a full range of potential options that it could recommend under the NRC's licensing, rulemaking, and oversight responsibilities. The staff noted some increases as well as some decreases in risk when the new HEAF methodology was applied; however, based on the results of the staff's assessments, the staff has concluded that there is no significant increase in risk warranting the need for any additional regulatory requirements. In addition, the staff evaluated various communication options that would enable the staff to share its insights with external stakeholders for licensee consideration to implement effective steps to further reduce and/or mitigate HEAF risks. The following summarizes the LIC-504 recommendations:

- Issue an Information Notice (IN) or Regulatory Issue Summary (RIS), as appropriate, and consistent with the Generic Communication process. The generic communication will share information on (1) the operating experience and risk insights from the LIC-504 assessment; (2) regulatory framework/license conditions and (3) the availability of the new HEAF risk assessment methodology for licensee consideration, which is expected to be issued for public comment by the end of July 2022 (see Recommendation 7 for details).

- Incorporate risk insights obtained from the LIC-504 assessment to inform NRR's ongoing PRA configuration control initiative (see Recommendation 8 for details).

- Consider incorporating risk insights obtained from the LIC-504 assessment to inform NRR's Reactor Oversight Process (see Recommendation 11 for details).

- Communicate risk insights gleaned from the HEAF-related risks/LIC-504 process with regional inspectors and Senior Reactor Analysts (SRA) using existing processes (KM-related meetings, Inspector Newsletters, periodic meetings between APLB and fire protection inspectors, SRA counterpart meetings) (see Recommendation 9 for details).

- Share risk insights gained from the HEAF LIC-504 analysis with external stakeholders via public meetings (e.g., workshops), participation at owners group meetings, and communications at national and international forums (see Recommendations 12, 13, and 14 for details).

Enclosures
1. Quantitative Risk Assessment
   Based on Reference Plants (ML22201A001)
2. Risk Insights Based on Operating Experience
   Including Accident Sequence Precursors
   (ML22201A002)
3. Summary of the Evaluation of Recommendations
   (ML22201A003)
4. Management Decision (ML22202A493)

SUBJECT: HIGH ENERGY ARCING FAULTS LIC-504 TEAM RECOMMENDATIONS
Dated July 22, 2022

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