Fire Research Plan
FY2018 – FY2022

Rev. 8 (03/28/18)

Fire and External Hazard Analysis Branch (FXHAB)
Division of Risk Analysis
Office of Nuclear Regulatory Research

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1 INTRODUCTION

The Office of Nuclear Regulatory Research (RES) is a U.S. Nuclear Regulatory Commission (NRC) office that supports the agency mission by providing independent technical analysis and advice, tools, and information for identifying and resolving safety issues, making regulatory decisions, and promulgating regulations and guidance for nuclear power plants and other facilities and materials regulated by the agency. RES has developed a process to capture the scope and content of requested technical products and services and to communicate with the requesting offices the extent of services and deliverables. This process provides schedules for delivery, identification of stakeholders, and documentation of agreements and approvals.

This process ensures that RES develops a complete and mutually agreed-upon work request (WR) and corresponding project plan prior to the commencement of work. Formalizing WRs ensures that the work is adequately vetted among technical staff and management. The different WR levels are based upon the magnitude of work (duration and costs) and the level of management approval necessary to invoke the proper level of RES resources to meet the needs of the WR. The four levels of WRs for RES technical support are:

- Research Assistance Request (RAR)
- User Need Request (UNR)
- Informal Assistance Request (IAR)
- Research Plan (RP)

The UNR and RAR memoranda are the principal mechanisms that the other offices use to request RES support. For requests for a limited level of effort, the offices may use an IAR to request RES support. When the request for research support services are broader or longer term, RES may develop an RP to better plan, execute, and track the research. RPs should be reviewed and concurred on by the affected office(s). An RP may cover multiple existing WRs and include other work such as longer-term research or ongoing support for codes and models.

This Fire Research Plan describes a set of research projects and tasks that RES will implement to maintain and enhance the NRC's regulatory approach with regard to fire protection. Specifically, this plan describes necessary research in the area of fire, including: 1) fire and electrical circuit analysis, 2) fire hazard analysis, 3) high energy arc faults, 4) fire probabilistic risk assessment (PRA), including human reliability analysis, and 5) ongoing actives such as training and frequently asked questions (FAQ) support. This plan focuses on specific areas of research to ensure realism in the performance of the commission licensing and related regulatory functions. The plan is designed to support refinement of regulatory tools (e.g., fire hazard characterization, circuit analysis guidance, PRA method advancements), and oversight activities (e.g., significance determination process, training) of operating facilities. This plan covers research to be undertaken during Fiscal Years (FY) 2018–2022.

Fire safety research performed by the NRC provides data, methods, and tools necessary to support agency oversight of regulated nuclear facilities. Historically, research in this area has provided a common understanding of the potential effects of fire on nuclear safety. Over the past four decades, the focus of the NRC's fire research program has shifted. In the 70's and 80's, confirming the effectiveness of the fire protection rule was of primary importance. Subsequent fire research performed through the 90's focused on several topical issues and progression of fire risk quantification approaches. Following the Commission's 1995 PRA policy

statement, the fire safety research was redirected to support one or more of the four functional areas of fire PRA, namely: prevention, detection and suppression, mitigation, and the quantitative evaluation of fire safety. This effort led to the development of joint report NUREG/CR-6850/EPRI 1011989, *NRC-RES/EPRI Fire PRA Methodology for Nuclear Power Facilities*, for performing a fire PRA and was issued in 2005.

When issued, NUREG/CR-6850 represented the most advanced and complete methodology for performing a fire PRA for a nuclear facility. However, the level of detailed analysis and expertise required was quickly evident shortly after nearly one-half of the US nuclear fleet began to develop fire PRAs. During this time, the NRC's fire safety research was focused on supporting the regulatory needs of reviewing the adequacy of licensee transitions to risk-informed, performance-based fire protection programs. Work performed to support the NFPA 805 transition was requested under Office of Nuclear Reactor Regulation (NRR) User Need NRR-2008-003, *Office of Nuclear Regulatory Research Technical Support for Nuclear Reactor Regulation National Fire Protection Association 805 Transition Program and other On-going Fire Protection Activities*.

The first wave of utilities volunteering to transition to the performance-based requirements of 10 CFR 50.48(c) are nearly complete, with only a few units under review or planned to summit a license amendment request. Much of the work requested under the user need has been completed, or determined to be no longer needed. As such, the focus of the fire safety program needs to be re-aligned to ensure that the work performed by RES is capable of supporting ongoing and emergent work encountered by the agency.

Learning from the substantial amount of effort performed by industry and NRC staff, several areas where additional research can be beneficial to enhancing fire PRA realism by improving the tools, methods, and data have been identified and in doing so potentially reduce regulatory burden. The result being an NRC fire protection oversight system which embodies the principles of good regulation.

On October 3 – 5, 2017, NRC held a public meeting with the nuclear power industry and other stakeholders to discuss fire PRA realism. During this meeting, a number of potential improvements were identified that could add realism to fire PRAs. Some of these improvements could be addressed under the frequently asked questions (FAQs) program while others would require more extensive research efforts. This Fire Research Plan includes tasks to address many of the topics identified during the meeting. Some of these efforts will focus primarily on confirmatory review of industry proposed methodologies while others will require independent research by NRC or joint efforts with the Electric Power Research Institute (EPRI).

2 OBJECTIVE AND SCOPE

The objective of this Fire Research Plan is to detail programs to support NRC's mission to protect public health and safety, and the environment. Elements of the research plan are intended to ensure research capability to address emerging regulatory needs, ensure realism in regulatory guidance and methods, and to support improving and maintaining the knowledge and tools needed to support regulatory oversight activities. This plan identifies specific technical areas to be addressed, discusses the specific tasks associated with each technical area, and presents the underlying rationales, products, projected schedules, and estimated resource requirements. In developing this research plan, NRC staff identified projects that address specific regulatory issues or requirements through discussions with other NRC offices and stakeholders. Many of these projects support implementing performance-based approaches and conducting regulatory oversight functions. Other research activities are intended to independently assess the adequacy of proposals or approaches forwarded by industry. In all cases, research has been focused and designed to meet the regulatory goals of the NRC and regulatory products have been identified. Issues related to individual plants or that are best investigated by industry are not included in this research plan.

Table 1 provides a summary of the fire research activities discussed in this Fire Research Plan. For the most part, the activities identified in this Fire Research Plan are independent and NRC offices can chose to support specific tasks or combinations of tasks through user need requests. This Fire Research Plan will be updated periodically to include any future fire research activities that may be necessary to support the agency's regulatory needs. In addition, the staff will revise this plan to include additional research that may be appropriate to support the review and licensing of evolutionary nuclear reactor designs, based on requests.

Table 1. Summary of Fire Research Activities

Task	Project	Regulatory Application
Near Term Completion – 1 year or less		
1	Revision to NUREG/CR-7150, Volume 1	Deterministic and RI/PB licensing & inspection (NUREG/CR-6850: Tasks 9 and 10, Appendices I, J, and K)
2	Instrumentation Circuit Functionality Testing (Small-Scale)	Results will provide basis for HRA assumptions and circuit analysis guidance update. Relief from assuming worst case may be possible depending on results. Results support guidance revision, inspection and licensing activities. (NUREG/CR-6850: Tasks 9 and 10, Appendices I, J, and K)
3	Post Fire Safe Shutdown Training	Required course work for IMC 1245 Appendix C-7 (attendance at or self-study)
4	Effectiveness of Cable Coatings	Current guidance is generic and difficult to interpret. Research will provided technical basis and refined guidance for crediting cable coatings in a fire PRA. Improve ignition, HRR, flame spread, and functionality FPRA guidance (Apx Q. NUREG/CR-6850)
Cooperative Research: Completion 2 years or less		
5	Obstructed Plume Zone of Influence (ZOI)	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Tasks 8 and 11)
6	Electric Pump and Motor Heat Release Rates (HRRs)	RI/PB licensing applications, method enhancement(NUREG/CR-6850: Tasks 8 and 11, Appendix G)
7	Cabinet to Cabinet Fire Propagation	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Tasks 8 and 11, Appendix S)
8	Main Control Board Fire Modeling	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Appendix L)

Task	Project	Regulatory Application
9	Fire Location Factor (Wall and Corner Effects)	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Tasks 8 and 11, Appendix S)
10	Transient Fire Heat Release Rates (HRRs)	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Tasks 8 and 11, Appendix G)
11	Probability of Propagation for Transient Fires	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Tasks 8 and 11, Appendix G)
12	Fire Progression Event Tree (Non-suppression Probability)	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Tasks 8 and 11, Appendix G)
13	Credit for Plant Personnel Fire Suppression	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Tasks 8 and 11, Appendix G)
14	Joint High Energy Arc Fault Activities with EPRI	RI/PB licensing applications, method enhancement
15	Main Control Room Abandonment (MCRA) – Human Reliability Analysis	High priority for risk-informing and providing improved realism in fire HRA/PRAs. Importance of MCRA scenarios is expected to be increased because recent research has resulted in an increase in the frequency of MCR board fires. Also, this research will address issues related to command and control, and local actions, which are important to other PRA hazards, as well as fire PRA.
Longer Term Research: Completion 4 years or more		
16	High Energy Arc Fault (HEAF)	RI/PB licensing applications, method enhancement (NUREG/CR-6850: Appendix M)
17	NUREG/CR-6850 Fire Growth Methodology Revision	RI/PB licensing applications, method enhancement to improve fire PRA realism (NUREG/CR-6850: Tasks 8 and 11, Appendix G)
18	Split of Bin 15 Fire Ignition Based Frequency	Refined bin frequencies will make fire PRAs more realistic. (NUREG/CR-6850: Tasks 8 and 11, Appendix G)

Task	Project	Regulatory Application
19	Revise NUREG-1805, Fire Dynamics Tools (FDT^s)	RI/PB licensing applications, method enhancement to improve fire PRA realism
20	Large Scale Instrumentation Circuits Spurious Operations	
21	In-Cabinet Spurious Operations	
22	Digital Instrumentation and Control (I&C)	
23	Knowledge Management	
24	Very Early Warning Fire Detection System (VEWFDS)	Coordinate testing and analysis activities through the EPRI MOU to provide supportive data for additional VEWFDS credit.
International Work: Completion 5 years		
25	PRISME III	Method enhancement to improve fire PRA realism
Frequently Asked Question (FAQ) Review		
26	Frequently Asked Questions (FAQ) Review General Support	Results are continuously used to support NFPA 805 reviews and clarification to current guidance.
27	Transient Controls Physical Analysis Unit (PAU) (FAQ 14-007	
28	Cable Tray Ignition at 500 °C (FAQ 16-11)	(NUREG/CR-6850: Tasks 8 and 11, Appendix R)
29	NUREG-2180 Enhancement (FAQ 17-012)	(NUREG/CR-6850: Appendix P)
30	Improved HEAF Non Suppression Probability (FAQ 17-013)	(NUREG/CR-6850: Appendix P)

Task	**Project**	**Regulatory Application**
31	HEAF Event Frequency 1E/non-1E	
32	Plant Trip Probability	
33	Updated Electrical Cabinet Non Suppression Probability (NSP) Curve	
34	Fire Damages Only Part of Equipment in Cabinet	
35	Reduce NSP Floor from 1E-3 to 1E-5	
Ongoing Work: Miscellaneous Support		
36	NRC-RES/ EPRI Fire PRA Training	"All five modules are required courses for IMC 1245 Appendix D-3. Module 1 is a requirement for branch specific qualifications journal (NRR - Appendix M) Module 2, plus one other module can be taken as an alternative to safe shutdown / circuit analysis training in IMC 1245 C-7"

3 FIRE RESEARCH PLAN ACTIVITIES

Near Term Completion – 1 year or less

3.1 Task 1: Revision to NUREG/CR-7150, Volume 1

NUREG/CR-7150 consists of three volumes developed in series to support both deterministic and performance-based approaches to safe shutdown circuit analysis. As the individual phases of NUREG/CR-7150 evolved, new information was developed. In several cases, this new information conflicted with earlier recommendations. For example, Volume 1 provided qualitative recommendations on the classifications of certain failure modes. Subsequent to these qualitative recommendations, numerical likelihood estimates were developed. In several instances, the numerical estimate do not comport with the qualitative recommendations. Volume 3 presents technical recommendations that update or clarify certain positions developed in earlier research efforts. Therefore there is information in Volume 1, which conflicts with Volume 3. The purpose of this work is to resolve those differences and make the documents consistent by revising Volume 1 to incorporate the new information, technical consensus recommendations and to make several clarifications with directly support regulatory oversight.

Deliverables:
Joint NRC/EPRI Report NUREG/CR-7150, Vol. 1, Rev. 1

Schedule:

Draft NUREG/CR-7150, Vol. 1, Rev. 1	Second Quarter 2018
Final Revised Report	Fourth Quarter 2018

Collaborators:
Electric Power Research Institute

3.2 Task 2: Instrumentation Circuit Functionality Testing (Small Scale)

Failure modes and effects from fire-induced damage to control and power cable are well understood. The failure modes of instrumentation circuits are not well understood. The impact of the failure mode from an HRA perspective are unknown. Current guidance and methods for both deterministic and probabilistic approaches typically assume fire-induced damage to instrumentation cables make the system unavailable. Industry testing performed in 2001 indicated different circuit response depending on the type of instrument cable under test, including long duration leakage current failure mode in thermoset cables, which could cause erroneous indication. The limited number of tests, specimen and circuit variations was insufficient to provide empirical evidence of the parameters that influence the failure modes of instrumentation cable.

The objective of this research is to perform a scoping study to understand the fire-induced failure modes of instrumentation cables and evaluate the potential effect those failure modes could have on plant instrumentation circuits (i.e., circuit, component, and/or system response). Small-scale radiant panel testing has been performed at SNL, and the results are being documented. Large scale testing originally proposed to support this work will not be performed at this time due to resource limitations and lack of interest from external stakeholders and NRR.

Deliverables:
Final NUREG Test Report

Schedule:
Final Test Report Fourth Quarter 2018

Collaborators:
Sandia National Laboratories

3.3 Task 3: Post Fire Safe Shutdown – NRC Inspector Training

Post-Fire Safe-Shutdown Analysis and Circuit Analysis are deterministic processes applicable to all NPPs regardless of licensing approach (prescriptive or performance-based). The assumptions and approaches to perform these analyses have evolved since the fire protection rule was issued in the early 80's. A combination of research, generic communications, improved guidance, and enforcement actions have resulted in a clearer understanding of the assumptions and analytical techniques used to perform these analyses. However, enforcement actions have resulted in the loss of knowledge and skills needed to understand and perform an inspection of a licensee post-fire safe-shutdown analysis and circuit analysis. RES training has been developed and offered to address this need.

The course teaches the fundamentals of operations, licensing and inspection of commercial NPPs and provides knowledge and skills needed to verify conformance to deterministic requirements governing the fire protection of safe shutdown capability (10CFR50.48, Appendix R to 10CFR50 or Section 9.5-1 of NUREG 0800) as specified in the plant-specific fire protection licensing basis.

The training is specifically designed to prepare NRC inspectors (of all levels) with knowledge to conduct deterministic assessments of post fire safe shutdown capability, including the systems and equipment necessary to achieve safe shutdown conditions in the event of fire or the design and operation of electrical distribution and control systems. This course is being formatted as an iLearn self-paced computer based training (CBT) and will be referenced under MC1245 inspector qualification program, as appropriate.

Deliverables:
Course covering post-fire safe shutdown analysis, circuit analysis, and associated inspection techniques.
Handbook/NUREG-1778

Schedule:
Handbook/NUREG-1778 Second Quarter 2018
Self-paced course: Fourth Quarter 2018

Collaborators:
Brookhaven National Laboratory
Sandia National Laboratories

3.4 Task 4: Effectiveness of Cable Coatings

Test data on cable coatings has been limited to experiments performed by Sandia National Laboratories in the late 1970's, and documented in NUREG/CR-2607, *Fire Protection Research Program for the U.S. Nuclear Regulatory Commission 1975-1981*, and NUREG/CR-0381, *A Preliminary Report on Fire Protection Research Program Fire Barriers and Fire Retardant Coatings Tests*. These reports conclude that the various coatings provide some measure of protection, but the results varied widely among the different manufacturers. The guidance for considering cable coatings in fire PRAs is contained in Appendix Q of NUREG/CR-6850 based on the 1970's large-scale fire tests.

In the past several years, experiments have been conducted at Sandia National Laboratories as part of the REBECCA-FIRE (Response Bias of Electrical Cable Coatings at Fire Conditions) program to quantify the effect of cable coatings on the electrical functionality of heated cables. Other experiments have been conducted at the National Institute of Standards and Technology as part of CHRISTIFIRE (Cable Heat Release, Ignition, and Spread in Tray Installations during Fire) program to measure the basic thermo-physical properties of these coatings and to quantify the burning behavior of relatively small samples of coated cables.

Under the CHRISTIFIRE program, tests were performed to measure cable ignition temperature using a small convection oven. These measurements of uncoated cables were obtained in 2014. Additional experiments are underway to add the ignition temperature of coated cables to the available data set. As part of these tests the effects of four different fire retardant coatings on time to ignition and time to damage will be measured.

Results from these tests will be used to improve the guidance for crediting cable coatings in fire PRAs. The new guidance will replace Appendix Q of NUREG/CR-6850.

Deliverables:
Three-Volume NUREG report

Schedule:

Draft: NUREG Report	Fourth Quarter 2017
Final NUREG Report:	Fourth Quarter 2018

Collaborators:
National Institute of Standards and Technology
Sandia National Laboratories

Cooperative Research: Completion – 2 years or less

3.5 Task 5: Obstructed Plume Zone of Influence (ZOI)

RACHELLE-FIRE introduced the concept of the obstructed plume and its impact on the zone of influence (ZOI) surrounding a fire. Using the computational fluid dynamics (CFD) model Fire Dynamics Simulator to study plume flow, the horizontal zone of influence could be modified to account for fires within electrical enclosures similarly to the modifications to the vertical ZOI documented in NUREG-2178. Specifically, developing a modeling methodology for considering

the impact of the enclosure on the horizontal (radiation) zone of influence and the HGL could provide additional realism in fire PRA. This topic is being explored as part of the RACHELLE-FIRE II working group activities.

Deliverables:
Joint NRC/EPRI Methodology Report

Schedule:

Draft RACHELLE-FIRE II Report	Third Quarter 2018
Final Report	First Quarter 2019

Collaborators:
Electric Power Research Institute
National Institute of Standards and Technology

3.6 Task 6: Electric Pump and Motor Heat Release Rates (HRRs)

The electric pump and motor heat release rates recommended in NUREG/CR-6850 were derived from electrical cabinet test data and professional judgment. These values are known to be conservative. There is a need to revisit these heat release rates in light of new event experience and testing information. As part of the RACHELLE-FIRE II working group effort, new data and analysis are being used to develop revised heat release rate distributions for electric pumps and motors.

Deliverables:
Joint NRC/EPRI Guidance Report

Schedule:

Draft RACHELLE-FIRE II Report	Third Quarter 2018
Final Report	First Quarter 2019

Collaborators:
Electric Power Research Institute
National Institute of Standards and Technology

3.7 Task 7: Cabinet to Cabinet Fire Propagation

Currently, it assumed that cabinet to cabinet propagation will occur after 10 minutes unless certain conditions are met. From testing and experience, this is a very conservative assumption. As part of the RACHELLE-Fire II working group efforts, new guidance for cabinet to cabinet propagation has been developed based on limited test data, fire event information, and professional experience. This guidance is linked to cabinet fire growth profiles.

Deliverables:
Joint NRC/EPRI Methodology Report

Schedule:
Draft RACHELLE-FIRE II Report Third Quarter 2018
Final Report First Quarter 2019

Collaborators:
Electric Power Research Institute
National Institute of Standards and Technology

3.8 Task 8: Main Control Board Fire Modeling (NUREG/CR-6850 Appendix L)

Operating experience (OE) suggests that control room fires do not propagated outside the sub-component level ignition source given rapid intervention by operators. The damage profile is conservative given the difficulty of identifying targets within the main control board. Research should be conducted to revise the fire growth/spread model for the main control board (MCB). OE suggests that fires are limited to the ignited components inside the MCB with no propagation. A heat release rate profile specific to the MCB should be developed to remove conservatism in existing approach. In addition, a methodology should be developed to properly apportion generic frequencies throughout the MCB.

Deliverables:
Joint NRC/EPRI Methodology Report

Schedule:
Draft RACHELLE-FIRE II Report Second Quarter 2019
Final Report Fourth Quarter 2019

Collaborators:
Electric Power Research Institute

3.9 Task 9: Fire Location Factor (Wall and Corner Effects)

The fire location factor is a parameter used to modify the plume equation for fires that are located near a wall or corner. Proximity to a wall or corner can reduce air entrainment into the plume resulting in higher plume temperatures and longer flame lengths. NUREG/CR-6850 has limited guidance regarding the implementation of the location factor. In an effort to improve this guidance, EPRI released Technical Report EPRI 3002005303, *Fire Modeling Enhancements for Fire Probabilistic Risk Assessment - Fire Location Factor, Transient Fires, and Liquid Spill Heat Release Rate*, in 2015. Among other things, this report provided guidance on implementation of fire location factors near wall and in corners for thermal plumes. The guidance was developed from a limited set of experimental data and a significant analysis of Fire Dynamics Simulator (FDS) calculations. Subsequent to the release of the EPRI report, the National Institute of Standards and Technology (NIST) conducted a series experiments, documented in NISTIR ####, with fires against walls, in corners, and in the open to develop additional data to improve understanding of wall and corner effects. This effort will use the NIST data to support validation of the wall and corner guidance provided in the EPRI report. The results will be published in

volume 2 of the joint NRC/EPRI report, *Refining and Characterizing Heat Release Rates from Electrical Enclosures during Fire (RACHELLE-FIRE)*.

Deliverables:
Joint NRC/EPRI Methodology Report

Schedule:

Draft RACHELLE-FIRE II Report	Third Quarter 2018
Final Report	First Quarter 2019

3.10 Task 10: Transient Fire Heat Release Rates (HRRs)

Transient fires are those where the fire is postulated in combustibles that are brought into an area on a “temporary” basis. Transient fires are separated into two categories: general transient fires and transient fires due to welding and cutting. The current modeling of transient fires includes a generic frequency, ignition source weighting, a geometry factor, a severity factor, and non-suppression probabilities. The ignition source weighting factor and the geometry factor are unique to transient fires. Modeling of the heat release rates and damage induced by transient fires in fire PRAs purportedly does not match operating experience. Transient fires have been the subject of several frequently asked questions (FAQs) and additional research by EPRI. Several utilities have used administratively-based “combustible controls” to address transient combustibles. In some cases, these combustible controls have placed limits on the maximum HRR of the transients that can be brought into an area. While these limits may have been derived from other guidance within NUREG/CR-6850, there is limited justification for their use. In addition, there is limited information available concerning the HRR of many transients that could be brought into an area making the combustible control limits difficult to enforce and verify.

EPRI has established a working group to develop improved guidance for modeling transient fires. This guidance will include development of a catalog of HRRs for typical NPP transient fuels. This information will support the justification and use of appropriate combustible control programs.

Deliverables:
Joint NRC/EPRI Guidance Report

Schedule:

Complete Testing of Transient Fuel Packages	First Quarter 2019
Draft Report on Transient HRR	Third Quarter 2019
Final Report	First Quarter 2020

Collaborators:
Electric Power Research Institute
National Institute of Standards and Technology

3.11 Task 11: Probability of Propagation for Transient Fires

In 2015, EPRI released Technical Report EPRI 3002005303, *Fire Modeling Enhancements for Fire Probabilistic Risk Assessment - Fire Location Factor, Transient Fires, and Liquid Spill Heat Release Rate*. Typically, the transient fire scenario considers only the likelihood of an ignition source and does not consider the probability that the ignition source would be of a size and location necessary to sustain a fire. The EPRI report provides a means to refine the NUREG/CR-6850 approach to include a term representing the probability that a transient fire develops into a significant fire event. This effort will integrate the methodology in the EPRI report with the results from Task 10 to develop improvements in the transient fire scenarios. This guidance will include development of a catalog of HRRs for typical NPP transient fuels. This information will support the justification and use of appropriate combustible control programs.

Deliverables:
Joint NRC/EPRI Guidance Report

Schedule:

Complete Testing of Transient Fuel Packages	Third Quarter 2019
Draft Report on Transient HRR	First Quarter 2020
Final Report	

Collaborators:
Electric Power Research Institute
National Institute of Standards and Technology

3.12 Task 12: Fire Progression Event Tree (Non Suppression Probability)

Operating experience suggests that a majority of fires do not generate damage outside the ignition source. Insights from the Electric Power Research Institute skyline chart suggest the focus should be on electrical cabinets. The current methodology does not acknowledge the different fire progressions that can occur. The current treatment of characterizing each fire parameter independently coupled with aggressive fire growth can result in a large percentage of severe fires. A technical basis should be developed for treating potentially challenging (PC) and challenging fire differently. In addition, a fire progression event tree should be developed to support fire quantification based on the characteristics and attributes of different ignitions sources.

Deliverables:
Joint NRC/EPRI report

Schedule:

Draft report	Second Quarter 2019
Final publication	Fourth Quarter 2019

Collaborators:
Electric Power Research Institute

3.13 Task 13: Credit for Plant Personnel Fire Suppression

Operating experience (OE) suggests that plant personnel routinely detect and suppress fires before growth or propagation. Personnel suppression credit only applied for continuously occupied rooms (e.g. main control room) and continuous fire watch (hot work). OE suggests that personnel detection and suppression is applicable to a wider range of ignition sources. Methods and data should be developed to credit plant personnel suppression more realistically in the fire scenario progression. A more realistic treatment of fire growth/progression for different ignition sources will be need to be developed.

Deliverables:
Joint NRC/EPRI report

Schedule:

Draft report	Second Quarter 2019
Final publication	Fourth Quarter 2019

Collaborators:
Electric Power Research Institute

3.14 Task 14: Joint High Energy Arc Fault Activities with EPRI

The NRC has recently completed an investigation, conducted as part of an international OECD project, into the zone of influence (ZOI) from high energy arc fault (HEAF) events. During this investigation, a potential vulnerability was identified where existing analytical models supporting plant specific safety analyses may be non-conservative. This vulnerability exists for electrical equipment that include components made of aluminum when subjected to HEAF conditions. The recent testing indicated that the area damaged around the equipment or the “zone of influence” (ZOI) may be larger than postulated in the current methodology for HEAF analysis, NUREG/CR – 6850 EPRI 1011989 “EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Volume 2: Detailed Methodology”. The presence of aluminum can create a more energetic plasma arc, that under some circumstances, can cause larger damage scenarios to electrical enclosures and/or transport high energy gaseous particles and plasma farther than previously assumed. In addition, dispersal of electrically conductive aluminum byproducts can result in previously unanalyzed failure modes.

In addition to the international OECD HEAF effort, which primarily is investigating the HEAF ZOI, there is a general consensus among industry members to pursue refinements to additional aspects of the HEAF modeling methodology. This effort will explore opportunities for improving realism in HEAF fire PRA and lay the foundation for modeling techniques once the larger research HEAF testing program is complete by revising the following four distinct areas/parameters;

1) HEAF definition
The current HEAF definition is unique to NPP applications and requires a large degree of analyst interpretation. The goal of this effort moving forward is to work with the appropriate national consensus standard committees to clarify the different level of arc fault events.
2) HEAF frequency
New frequencies will be required to correlate with the new HEAF definitions. Possible frequency categories may be required for 1E vs. non-1E equipment, low voltage vs. medium voltage equipment and bus ducts.
3) HEAF event tree modeling tools
Prior to the development of refined ZOI distances modeling advancements can be established defining the appropriate frequency and non-suppression values to be used for scenario development.
4) HEAF timing analyses
One identified parameter of significant importance for the severity of a HEAF event is the duration the fault persists. The working group will work with industry and EPRI to investigate the potential to predict possible fault durations based on plant configuration and design attributes. This information will be a necessary parameter for modeling.

Deliverables:
Joint NRC/EPRI report.

Schedule:

Draft Report	Second Quarter 2019
Public Comment	Third Quarter 2019
Final Publication	First Quarter 2020

Collaborators:
Electric Power Research Institute
Sandia National Laboratories

3.15 Task 15: Main Control Room Abandonment – Human Reliability Analysis

Working jointly under a Memorandum of Understanding, the Electric Power Research Institute (EPRI) and the U.S. Nuclear Regulatory Commission's Office of Nuclear Regulatory Research (NRC-RES) published EPRI 1011989 / NUREG/CR-6850, Fire PRA Methodology for Nuclear Power Facilities. While NUREG/CR-6850 developed methods, tools and data for performing at-power fire probabilistic risk analysis, it did not identify or produce a method to develop best-estimate human error probabilities (HEPs) given the performance shaping factors (PSFs) and the fire-related effects.

Following the publication of NUREG/CR-6850, a subsequent joint effort produced EPRI 1023001/NUREG-1921, EPRI/NRC-RES Fire Human Reliability Analysis Guidelines - Final Report to fulfill the need for explicit human reliability analysis (HRA) on performing both qualitative and detailed quantitative analysis to support best-estimate human error probabilities in fire PRAs. However, while NUREG-1921 represents an advancement in HRA practice, it

identifies a few areas that would benefit from further research. One of those areas is the treatment of main control room abandonment and associated shutdown strategies.

Following publication of NUREG-1921, the industry proposed fire PRA Frequently Asked Question (FAQ) 13-0002 in response to recurring requests for plants transitioning to NFPA 805 to justify the screening value used or provide a detailed analysis for main control room scenarios. The FAQ was intended to address a long-standing concern regarding the use of "screening" human error probabilities (HEPs) for modeling failure to successfully abandon the main control room due to fire in the main control room and transfer functions necessary to maintain safe shutdown capability to alternative location(s). After considerable effort by both industry and the NRC, it was recognized that more research was needed.

RES, in cooperation with EPRI, is developing expanded guidance for addressing fire PRA scenarios that involve abandonment of the main control room. This guidance will build upon that already provided in the Joint EPRI/NRC-RES Fire Human Reliability Analysis Guidelines (NUREG-1921, EPRI 1023001) and in the closeout of FPRA FAQ-13-0002. The scope of the expanded guidance will include loss of habitability and loss of control scenarios that result in main control room. In addition, the expanded human reliability analysis guidance will address differences in safe shutdown strategies related to plant-specific operational and design characteristics. Because of the wide variety of such plant-specific operational and design characteristics, illustrative examples of associated shutdown strategies are expected to be needed (as opposed to the more generic approaches used to address in-control room operator actions). The examples should include, if appropriate, any strategies that are or are similar to the so-called "self-induced station blackout," or SISBO. Also, to the extent possible, guidance should be provided for HRA analysts to address instances where the plant-specific operational and design characteristics do not exactly match any of the illustrative examples.

This research effort will result in two supplements to NUREG-1921: supplement 1 will document the qualitative analysis and supplement 2 will provide quantitative guidance. The first product, Supplement 1 - qualitative analysis, which included a peer review and presentation to the ACRS PRA Subcommittee, is available on EPRI's website and is being prepared for NRC publication (expected submittal in September 2017). Development of the quantification guidance is expected to involve a draft for public comment and testing, in addition to the same activities completed for Supplement 1. This task is considered a high priority for risk-informing and providing improved realism in fire HRA/PRAs. Since recent research results indicate higher MCR board fire frequencies, the importance of MCRA scenarios is expected to increase. Also, this research will address issues related to command and control, and local actions, which are important to other PRA hazards, as well as fire PRA. EPRI will publish NUREG-1921 Supplement 1, on qualitative analysis, and support development of quantitative guidance. NRC supported the development and publication of Supplement 1, as well as the development of Supplement 2.

Deliverables:
Two joint NRC/EPRI reports as supplements to NUREG-1921.

Schedule:

NUREG-1921 Supplement 1 - Qualitative Analysis	Fourth Quarter 2017
NUREG-1921 Supplement 2 - Quantification Guidance	
Draft report	Third Quarter 2018
Testing at nuclear power plant sites	Fourth Quarter 2018

Peer review	First Quarter 2019
Final publication	Second Quarter 2019

Collaborators:
Electric Power Research Institute
Sandia National Laboratories

Longer Term Research: Completion 4 years or more

3.16 Task 16: High Energy Arc Fault (HEAF)

The NRC has recently completed an investigation, conducted as part of an international OECD project, into the zone of influence (ZOI) from high energy arc fault (HEAF) events. During this investigation, a potential vulnerability was identified where existing analytical models supporting plant specific safety analyses may be non-conservative. This vulnerability exists for electrical equipment that include components made of aluminum when subjected to HEAF conditions. The recent testing indicated that the area damaged around the equipment or the “zone of influence” (ZOI) may be larger than postulated in the current methodology for HEAF analysis, NUREG/CR – 6850 EPRI 1011989 “EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Volume 2: Detailed Methodology”. The presence of aluminum can create a more energetic plasma arc, that under some circumstances, can cause larger damage scenarios to electrical enclosures and/or transport high energy gaseous particles and plasma farther than previously assumed. In addition, dispersal of electrically conductive aluminum byproducts can result in previously unanalyzed failure modes.

Many OECD member countries are planning to continue supporting the NRC lead HEAF research effort. The proposed research will investigate the impact of both copper and aluminum components on HEAF severity. The data from the copper component tests will provide a baseline for comparison with the aluminum component results support development of new or modified ZOIs for HEAF events. A draft test plan for this next phase of HEAF testing will be presented to the CSNI panel in December of 2017. OECD member participation will be through the donation of equipment to be tested and/or in-kind monetary contribution based on the final scope of the project test plan. This international collaboration will ensure the experimental program can be conducted in the most cost effective manner and with the most technical experience available on an international platform.

The results from these test series as well as HEAF testing being conducted by the Japanese Nuclear Regulatory Authority (JNEA) in combination with operating experience and other HEAF test data, will be used by the international team to develop consensus conclusions on HEAF behavior, understand the potential for HEAF damage including ensuing fires, establish HEAF evaluation criteria to support Fire Hazards Analyses (FHA), and recommend protection measures. NRC conducted an international Phenomena Identification and Ranking Table (PIRT) exercise on HEAF in February 2017 as part of the OECD project to support interpretation of the results, identification of additional data needs, and development of improve HEAF ZOI estimates.

Research to further evaluate the impact of aluminum components on the severity of HEAF events has been recommended by the Generic Issues Review Panel (GIRP). The GIRP review panel recommended a two stage approach along with short term and long term actions to

resolve the issues. The GIRP recommendations and screening report can be found in ADAMS package ML16349A027. The first necessary action will be a scoping study to determine the risk importance of an increased damaged state from aluminum. The resources needed for this task will largely depend upon the interaction and involvement of industry. RES will attempt to work with EPRI through the MOU to establish pilot plants and direct risk scoping activities with the potential need for confirmatory plant walk-downs. The second action will be to conduct further testing with the OECD to inform the risk quantification of HEAF phenomena for realistic characterization in fire PRA.

Deliverables:
NUREG/IA-0470 Volume 2
OECD or NUREG PIRT Report
Risk Assessment Study
Testing - CSNI Report documenting test results and analysis
Revisions to Appendix M of NUREG/CR-6850

Schedule:

Risk Assessment Study	To be determined
Draft Test Plan	Third Quarter 2017
Test Plan Submitted to CSNI	First Quarter 2018
OECD or NUREG PIRT Report	First Quarter 2018
NUREG/IA-0470 Volume 2	Second Quarter 2018
HEAF Testing	First Quarter 2020
NUREG/CR-6850 Appendix M Revisions	Fourth Quarter 2020
Draft Test Report and Analysis	First Quarter 2021
Final Report Submitted to CSNI	Third Quarter 2021

Collaborators:
Nuclear Regulation Authority of Japan
Organisation for Economic Cooperation and Development (OECD)
National Institute of Standards and Technology
KEMA Laboratories
Brendan Stanton Electrical Contractors
Sandia National Laboratories

3.17 Task 17: NUREG/CR-6850 Fire Growth Methodology Revision

Research conducted since publication of NUREG/CR-6850 (EPRI 1011989) has yielded significant improvements in the tools, methods, and data used for fire PRAs. RES working both independently and jointly with EPRI continues to conduct research in areas where realism in fire PRA can be improved. Despite these improvements, many fire PRAs are still considered overly conservative. Some of the increased realism and other benefits resulting from the improvements have been limited by the need to incorporate them into the existing NUREG/CR-6850 framework. To gain significant additional improvements in fire PRA realism, it is necessary to explore new methods for coupling fire frequencies, HRR distributions, fire growth profiles, and fire suppression effectiveness.

The fire PRA methodology documented in NUREG/CR-6850 includes two tasks that involved use of fire modeling. Specification of the heat release rate (HRR) is a key component in the use

of fire modeling. The HRR profile is typically divided into four stages: incipient, growth, fully developed, and decay, however, the four stages are not observed in all fires. NUREG/CR-6850 provides HRR guidance for three general types of fuel ignition sources typically found in nuclear power plants, fixed ignition sources, flammable liquids, and transients.

For a flammable liquid spill, the HRR profile can be readily developed from the properties of the combustible liquid and the size of the spill. For fixed ignition sources and transients, HRR profiles can be developed using peak HRR distributions and growth, steady-state, and decay times. NUREG/CR-6850 provides peak HRR distributions for electrical cabinets, pumps, motors, and transient ignition sources. It also recommends a fire growth time of 12 minutes using a t-squared fire growth rate and a peak burning time of 8 minutes for electrical cabinet fires. These peak HRR values and HRR profile times were developed based on a limited set of experiment data and expert judgement. NUREG/CR-6850, Supplement 1 (EPRI 1019259) recommends a growth time of 8 minutes for common NPP trash in plastic or metal receptacles and 2 minutes for trash in plastic bags. Using additional test data and expert judgement, new peak HRR distributions for electrical cabinets were published in NUREG-2178, volume 1 (EPRI 3002005578).

This effort will explore opportunities for improving realism in fire PRA by revising the following three distinct areas/parameters;

1) T-squared growth rate
2) Time to reach peak HRR
3) Steady-state/decay time

These areas will be evaluated by using existing experimental data, forensic analysis of industry operating experience, and expert judgement. This effort will explore opportunities for improving realism in fire PRA by revising all aspects fire growth curve. This effort builds on the new electrical cabinet bins developed in NUREG-2178, volume 1 and other efforts to further resolve NUREG/CR-6850 ignition sources, this effort will attempt to develop generic HRR profiles for different types of electrical cabinets and other ignitions sources. It is expected that revising the methodology for developing the HRR profiles will add realism to the specification of the fire scenarios used in the fire modeling portions of the fire PRA. In addition, it can facilitate the inclusion of other efforts to increase realism such as improved crediting of detection during the incipient phase, detection by plant personnel during routine activities, and modeling of fire suppression.

Deliverables:

Review testing and operating experience
Analyze data and develop recommendations to increase realism in fire growth profile
Validate new fire PRA methodology, tools, and data

Schedule:

Complete review of test data and operating experience	Third Quarter 2018
Analyze data and develop recommendations	Fourth Quarter 2019
Complete validation of new tools, methods and data	Third Quarter 2020
NUREG report documenting final methodology	Second Quarter 2021

Collaborators:

National Institute of Standards and Technology
Sandia National Laboratories

3.18 Task 18: Split of Bin 15 Fire Ignition Based Frequency

Task 6 of NUREG/CR-6850, fire ignition frequencies, divides potential plant fire sources into bins that represent location, causal and mechanistic factors deemed important to depict the likelihood of fire scenarios at different NPPs. The current methodology estimates fire-ignition frequencies and their respective uncertainties for different compartments (e.g., main control room and RHR pump room) and ignition sources (e.g., CCW Pump A and three vertical segments of a motor control center (MCC)). A generic set of fire ignition frequencies for various generic equipment types (ignition sources) typically found in certain plant locations was developed as a starting point. The combination of locations and equipment types (ignition source) are referred as ignition frequency bins represented by generic mean frequencies in terms of number of events per reactor year.

The current generic frequencies provided apply to all relevant equipment items within a unit. For example, in the case of "batteries," the mean frequency, 1.96E-04 per reactor year, applies to all battery sets of a unit that provides backup power to the DC buses. If there are two battery sets associated with one unit, the fire frequency per battery set would be 9.8E-05 per reactor year. If there are four battery sets in another one-unit plant, the mean frequency at that plant would be 4.90E-05 per reactor year for each battery set. As the example illustrates, the per-item fire ignition frequency may vary from plant to plant due to the variations in the total population of a given equipment type present in the plant. This methodology preserves the plant-wide fire frequency and assumes the battery fire plant wide fire frequency is the same for all units regardless of the equipment count.

There has been a growing need for component-based fire frequencies and a switch away from generic fire frequencies as fire PRA's become more detailed and scenario specific. With the publication of RACHELLE-FIRE, the need for electrical cabinet frequencies broken down into cabinet type becomes more necessary. For example, a breakdown of frequency into cabinet type will enable the PRA to more accurately distinguish between the risk of low and high voltage electrical cabinets, as the HRR and frequency will be aligned for cabinet type. By determining a fire frequency on a component basis, the fire PRA's can be more accurately modeled. This task will involve a collaborative effort with EPRI and the PWR and BWR owners groups to develop component specific frequencies for use in Fire PRA's. It will be necessary to collect equipment count information from all plants contributing data to the FEDB update, NUREG-2169 and develop fire frequencies in accordance with the methodology presented in "An Improved Methodological Approach for Estimating Fire Ignition Frequencies (EPRI 1022994)".

Deliverables:
Report providing updated fire ignition frequency estimates and non-suppression probabilities

Schedule:

Draft:	Third Quarter 2019
Final NUREG Report:	First Quarter 2020

Collaborators:

3.19 Task 19: Revise NUREG-1805, Fire Dynamics Tools (FDT^{s})

NUREG-1805, *Fire Dynamics Tools (FDT^{s}) – Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program*, and Supplement 1 provide engineering tools to support quantification of risk scenarios in nuclear power plant applications. These tools have been verified and validated (V&V) in NUREG-1824 and its Supplement 1. Using comparisons with experimental data, these V&V efforts provide information on model bias and standard deviation. These values can be used to determine the relative confidence in the model calculations. Recent cooperative research with the Electric Power Research Institute has identified several calculation methods than can be updated to reduce the conservatism in the calculated results. This task will update the appropriate calculation methods contained in NUREG-1805 and verify and validate the new calculations. It is expected that the V&V effort will also include a review of the industry sponsored calculation suite, FIVE.

Deliverables:
Report

Schedule:
Final NUREG Report

Collaborators:
Electric Power Research Institute

3.20 Task 20: Large Scale Instrumentation Circuits Spurious Operations

Current guidance and methods for both deterministic and probabilistic approaches typically make conservative (bounding) assumptions regarding the fire-induced failure modes of instrumentation cables and failure mode effects on component and system response. Industry testing performed in 2001 indicated different circuit response depending on the type of instrument cable under test. The limited number of tests, specimen and circuit variations was insufficient to provide an empirical evidence of the parameters that influence the failure modes of instrumentation cable.

Between 2010 and 2014, the NRC and EPRI undertook efforts using expert judgment to characterize the propensity of specific failure modes and configurations to cause hot short-induced spurious operation of equipment due to fire damage. These efforts concluded that due to the low state of knowledge and potentially high consequence of fire-induced failure on instrumentation current loop circuits, additional testing is recommended. Additionally, recommendations were made to discontinue the use of the 'option 2' approach presented in NUREG/CR-6850 due to its inherent limitations (lack of realism) and that conditional probability estimates developed were not applicable to instrumentation type circuits. Thus, the recommended approach was to make conservative worst case assumptions regarding the failure state of the instrumentation circuits.

The objective of this research is to understand the fire-induced failure modes of instrumentation cables and evaluate the potential effect those failure modes could have on plant instrumentation

circuits (i.e., circuit, component, and/or system response). This work is intended to support future revisions to guidance (e.g., RG 1.189, NUREG/CR-6850) related to circuit analysis.

The objectives of this research will be accomplished by performing a comprehensive testing program evaluating common instrumentation circuit configurations found in nuclear facilities. EPRI will serve as a resource for ensuring configurations typically of nuclear facilities are being pursued for testing configurations. NIST will be the performing organization for testing and development of the report. EPRI and NRC-RES will collaborate on development of recommended guidance as part of the technical report or as a separate white paper.

Deliverables:
Report

Schedule:
Final NUREG Report

Collaborators:

3.21 Task 21: In-cabinet Spurious Operations

The failure modes and effects of fire damage to electrical cables has been evaluated through experimental testing performed by Industry and the NRC. The testing results were thoroughly reviewed by a team of industry and NRC expert to characterize the parameters that influence specific failure modes, which supported development of guidance for deterministic and performance based fire protection plans. Once a field routed cable enters an electrical enclosure, the configuration changes as the insulated conductors are routed outside of the protective jacket to be landed at various termination points. Because of the configuration differences, the results from the field route cables cannot be directly applicable to internal cabinets. Thus, the conductor configuration once inside the electrical enclosure can be much different than what has been tested in the past. As such, the questions arises: How will panel wiring response to severe fire conditions and what are those response impacts on equipment important to safe shutdown? As such, the NRC and Industry representatives have recommended using what is believed to be conservative estimates on the likelihood of fire damage causing spurious operations within an electrical enclosure. These conservative assumptions have resulted in a lack of realism in the methods and is viewed as an area where improvements to realism can be made.

The expert panel work documented in NUREG/CR-7150 Volumes 1-3, considered the fire-induced effects on panel wiring and concluded that the lack of test data clearly is problematic when determining the true behavior of conductors or components in a panel. Hence, it is important to determine the characteristics for in-cabinet configuration. With this in mind, the PIRT panel strongly recommended further testing in this area. The expert elicitation report concluded that the conservative use of the aggregate conditional spurious operation probabilities should be used. That report also recommended that additional testing should be performed, given the lack of applicable test data and the potential risk importance of panel wiring.

The objective of this research is to understand the fire-induced failure modes of panel wiring and evaluate the potential effect those failure modes could have on the plant (i.e., circuit,

component, and/or system response). This work is intended to support future revisions to guidance (e.g., RG 1.189, NUREG/CR-6850) related to circuit analysis.

The objectives of this research will be accomplished by performing a comprehensive testing program evaluating common panel wiring configurations found in nuclear power plants.
The purpose of this

Deliverables:
Report

Schedule:
Final NUREG Report

Collaborators:

3.22 Task 22: Digital Instrumentation and Control (I&C)

Fire hazard analysis and performance-based methods have focused primarily on the thermal effects from fire on the safe shutdown capability. However, fire also produces smoke and gasses that have the potential to impact the function of components relied on for achieving safe shutdown. Research and literature reviews have been performed in the past with little effort being expended to develop guidance to ensure system function are protected from the byproducts of fire. Internationally there has been research that shows the present of fire byproducts can reduce the thermal damage threshold for certain components. Because of the lack of understanding of the impact of fire byproducts on the functionality of electrical equipment, primarily digital equipment an effort to characterize this hazard and develop recommendations on possible protection features would bridge the current knowledge gap.

This effort would involve reviewing previous studies, and recent international efforts to identify potential areas for equipment vulnerability. Based on these results, either an experimental program, or guidance development would be conducted.

Deliverables:
Report

Schedule:
Final NUREG Report

Collaborators:
National Institute of Standards and Technology

3.23 Task 23: Knowledge Management

In 2006 the NRC formally established a knowledge management (KM) program thru the issuance of a formal KM policy (SECY-06-0164 "The Knowledge Management Program; Internal NRC Policy Issue information). Since then, the Fire and External Hazards Analysis Branch (FXHAB) has greatly supported the development and improvement of KM activities and

tools. A number of NUREG/BR's were initially published as part of the KM activities which include:

- NUREG/BR-0361: "The Browns Ferry Nuclear Plant Fire of 1975 and the History of NRC Fire Regulations"
- NUREG/BR-0364: "A Short History of Fire Safety Research Sponsored by the U.S. Nuclear Regulatory Commission, 1975-2008"
- NUREG/BR-0465: "Fire Protection and Fire Research Knowledge Management Digest"

These NUREG/BR served as tools to capture important reports, data, videos, seminars and other documents related to fire protection, and provide a roadmap of important fire events and research activities. Some of these NUREG/BRs have been upgraded into NUREG/KM documents. These include:

- NUREG/KM-0002 Revision 1: "The Browns Ferry Nuclear Plant Fire of 1975 Knowledge Management Digest"
- NUREG/KM-0003: "Fire Protection and Fire Research Knowledge Management Digest, 2013"

These NUREG/KMs serve as the knowledge base of Fire Protection with NUREG/KM-0003 being revised once every several years as resources permit. More specifically, the latest updates to NUREG/KM-0003 have served as a tool to help regional inspectors prepare for site inspections as well as improve the accessibility of inspection documents from sites in other regions.

FXHAB has established itself as the premier branch related to creating and publishing technical research KM. FXHAB staff has supported the development of other NUREG/KMs including the first NUREG/KM, NUREG/KM-0001: "Three Mile Island Accident of 1979 Knowledge Management Digest", and NUREG/KM-0005: "2002 Davis-Besse Reactor Pressure Vessel Head Degradation Knowledge Management Digest". The branch staff has also coordinated and conducted many successful workshops and seminars and actively supports the RES KM program. More recently the staff supported the development of the RES Seminar Logistics guide found under the RES KM program "related links" which consolidates lesson's learned from past seminars. FXHAB is available to support fire related and non-fire related KM activities of interest to the NRC as requested.

Deliverables:
Revision of NUREG/KM-0003 "Fire Protection and Fire Research Knowledge Management Digest" with documents published last update.

Other KM deliverables are identified during the fiscal year. This include workshops (i.e., October 2017 Fire PRA Realism Workshop), seminars and KM documents.

Schedule:

Revision to NUREG/KM-0003	First Quarter 2018
Reports on other topics as appropriate	

Collaborators:
All NRC Offices and Regions.

3.24 Task 24: Very Early Warning Fire Detection System

Guidance in NUREG-2180 provides treatment of a Very Early Warning Fire Detection Systems (VEWFDS), also called incipient detection, for fire prevention and targeted/enhanced suppression. Fire prevention comprises actions taken to preclude the first occurrence of flame, while targeted/enhanced suppression comprises actions taken after the first occurrence of flame and before fire growth to limit fire damage to the initiating component or cabinet.

For Bin 15 (Electrical Cabinets) fires, guidance is provided for both in-cabinet and area-wide applications. For Bin 4 (Main Control Board) fires, guidance is only provided for in-cabinet applications.

Section 6.1.1 of NUREG-2180 concerns the modification, as illustrated by Figure 6-6, of the suppression event trees presented in Section 6.4 to support a suppression strategy. Section 10.6.4 is described as providing the human failure event quantification items for a prevention strategy that should be considered when performing the detailed human reliability analysis.

According to draft licensee correspondence, properly crediting a fire prevention strategy is difficult because the fire events data base only documents events that resulted in fire, and success for early detection and prompt mitigating actions is not evident, As examples, a fire prevented is not counted as a fire event, in the typical sense. Also, the more quickly a fire is prevented during the incipient phase the less is actually known about the real duration of the incipient phase. However, the risk avoidance associated with a successful fire prevention strategy is considered significant. The industry believes that a situation exists where there is aversion to not want to over-credit something that is really unknowable, but also reduction in safety consequences to not accept assumptions or techniques that discourage a fire prevention strategy.

Areas where additional VEWFDS credit may be available is in categorization of pre-fire events that are not recorded in the fire events data base, but may reside in operator logs and alarm records to a level that could be useful to estimate increased detection capability of VEWFDS. Additionally, evaluation of operator actions and response in mitigating fire scenarios could result in recommendations for changes to current fire event strategies such that additional credit may be considered. Staff would work with EPIP in accordance with the EPIP/NRC MOU to assess whether different approaches offer opportunity to changes in PRA credit for VEWFDS.

Deliverables:

Schedule:

Collaborators:

International Work: Completion 5 years

3.25 Task 25: PRISME III

The PRISME 3 program is an Organisation for Economic Cooperation and Development (OECD) experimental fire program that grew out of the international collaborative fire modeling project. The NRC participated in PRISME 1, did not participate in PRISME 2, and will be participating in PRISME 3. Participation consists of financial support for the program, working group meeting participation, and access to the experimental results. The program will last from 2017 to 2022, and participants include: Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Electricité de France (EDF), Gesellschaft für Anlagen und Reaktorsicherheit (GRS), VTT Finland, NRC, Office for Nuclear Regulation (ONR), Institute for Building Materials, Solid Construction, and Fire Protection (iBMB), Korea Atomic Energy Research Institute (KAERI), Central Research Institute of Electric Power Industry (CRIEPI), Tractebel, and Bel V.

The PRISME 3 program objectives are to study a number of real fire sources to quantify fire behavior for use in probabilistic risk assessment (PRA) and fire modeling validation and verification (V&V). The PRISME 3 program is comprised of four experimental campaigns:

1) Smoke Stratification and Spread (S3)
   A total of five tests will be conducted in IRSN's DIVA facility. Two will focus on smoke propagation through openings, two will focus on smoke stratification and propagation from multi-fire sources, and one will focus on an elevated fire source.
2) Electric Cabinet Fire Spread (ECFS)
   A total of eight tests will be conducted; four under a calorimeter (SATURNE facility), and four in the DIVA facility. In each set of four, two experiments will focus on fire spread from an open-door cabinet to an adjacent cabinet separated by a double wall, and two will focus on fire spread from an open-door cabinet to electrical cables.
3) Cable Fire Propagation (CFP)
   A total of eight tests will be conducted. Two will be conducted under a calorimeter, and will study the effect of the cable tray configuration on the rate of fire spread. Three will study the effects of under-ventilated conditions on the fire behavior. The remaining three tests will study the behavior of fire spread in a service gallery configuration.
4) Complementary Tests (COMTE)
   This campaign is reserved to complete any of the previous campaigns, repeat tests as necessary, and perform confirmatory work.

The NRC will use the experimental results of the PRISME 3 project in two applications. Analytical results will be used to further validate commonly used fire models (FDS, CFAST, etc.) for which the NRC maintains a V&V guide (NUREG-1824). Expanding the repository of experiments incorporated into the V&V guide expands the range of validation and applicability of a model, and increases the accuracy of statistical measures used to predict model uncertainty and bias. Probabilistic results will be used to confirm or revise the guidance for fire PRA as specified in NUREG/CR-6850, particularly where cable fire spread and cabinet-to-cabinet fire spread are concerned.

Deliverables:
OECD reports documenting the experimental and probabilistic results of each test campaign to support improvements to fire PRA realism.

Schedule:

Campaign 1 Complete	First Quarter 2020
Campaign 2 Complete	Third Quarter 2020
Campaign 3 Complete	Second Quarter 2021
Campaign 4 Complete	Fourth Quarter 2021
Final Reports	Second Quarter 2022

Collaborators:
Organisation for Economic Cooperation and Development (OECD)

Frequently Asked Question (FAQ) Review

3.26 Task 26: Frequently Asked Question (FAQ) Review General Support

NUREG/CR-6850/EPRI 1011989 established the state of practice for fire PRA. NUREG/CR-6850 is being used by licensees to develop fire risk studies to support implementation of NFPA-805 and other PRA applications. As the use of the tools, methods, and data included in NUREG/CR-6850 increased, technical issues were identified that required additional guidance or clarification. The frequently asked questions (FAQ) program was developed to support expeditiously resolution of these identified issues.

Industry continues to submit NFPA 805 FAQs, which require considerable staff time and effort to review and work to resolution. In several instances, RES has the expertise to help supplement NRR's review. RES will support FAQ reviews as requested by NRR. Two specific FAQs are identified in Tasks 4 and 5.

Industry has submitted a report that documents three new method for use in fire PRA. A vetting panel effort has been established to review this report and evaluate the new methods for use in fire PRA. FXHAB is assisting with the review of EPRI TR 3002005303.

In fire PRA scenarios, cables within the fire zone of influence (ZOI) are typically assumed to propagate the fire. Industry has submitted FAQ 16-0011 'Cable Tray Ignition' with a method to characterize the potential for fire propagation to cable trays. While technically valid for the most part, the industry FAQ includes potentially non-conservative criteria for cable ignition temperature with little justification. Testing, conducted as part of the cable coatings project, has provided significantly more data on cable ignition criteria. RES will document these tests and the associated data analysis to develop technical valid and reasonable conservative ignition criteria.

NUREG-2180 was published in December 2016 provides deliverable to UNR 2008-03. Industry has submitted FAQ 17-0012 ‘Incipient Detection for Fire Prevention and Suppression’ to present a method of using Very Early Warning Fire Detection Systems (VEWFDS) as a fire prevention and targeted/enhanced suppression measure. RES will support a review of the FAQ and provide comments and feedback to NRR.

Deliverables:
Resolution of FAQs

Schedule:
Ongoing as necessary

Collaborators:
Will depend on complexity of the FAQ topic

3.27 Task 27: Transient Controls Physical Analysis Unit (PAU) (FAQ 14-0007)

The current methodology applies transient influence factors to physical analysis units (PAUs). However, it is likely that variations in the levels of maintenance, occupancy, storage, and hotwork exist within a PAU. While it is possible that an entire PAU is either a transient combustible free zone, a dedicated storage area, or has uniform characteristics, it is more likely that a PAU contains a mixture of spaces. These spaces may be made up of fire zones, rooms, or other administratively controlled areas (e.g. painted floors for transient free zones). The current methodology does not enable this to be reflected during the early phase of ignition frequency calculations. There is some flexibility in the scenario development phase to account for these variations. However, there is no clear guidance provided on how this should be accomplished.

The proposed enhancement is a change to the methodologies outlined in NUREG/CR- 6850, NFPA 805 FAQ 12-0064 as applied to a subset of a PAU, and FPRA FAQ 13- 0005. The proposed enhancement is to provide an approach that addresses variations of transient ignition frequency within a PAU during the fire ignition frequency task. The enhancement to the current methodology involves assigning influence factors not only to the PAUs, but also to Transient Ignition Source Regions (TISRs). TISRs are spaces smaller than PAUs that are identified to have varying transient ignition frequency characteristics. Examples of TISRs may include fire zones, rooms, transient free zones, dedicated storage areas, etc. TISRs should be based on administratively controlled areas to ensure that they are maintained by plant personnel.

The basis behind the TISR methodology for general transient fires and for transient fires from welding and cutting, which allows the influence factors to be weighted by floor area, is that a grid is established to determine the number and location of transients for a TISR. Due to the grid, a TISR with a larger floor area will contain a larger number of transients than a TISR with a smaller floor area. To apply this FAQ, the number of grid spaces across different TISRs should be proportional to the floor area of the different TISRs. The application of this FAQ ensures that the transient frequency is not diluted for larger areas due to the grid, and is not overemphasized for smaller areas. Thus to apply this FAQ, grids proportional to the floor area must be applied to evaluate the importance of transients for the fire frequency ignition bins of general transients and to evaluate transients from welding and cutting.

The approach to calculating the ignition frequencies for TISRs first involves assigning transient influence factor rankings to the TISRs in a similar manner to that performed for PAUs. The next step is to identify the size of each TISR. The size should be based on the available floor area and the amount of exposed cables for floor based transient fires and cable tray fires respectively. The next step is to determine the Transient Ignition Source Region Factors (TISRF). The final step to calculate ignition frequencies for TISRs is to multiply transient bin PAU frequency by the applicable TISRF.

Deliverables:
Support for Resolution of the FAQ

Schedule:
Documentation to Support Closure Memorandum Third Quarter 2018

Collaborators:
Electric Power Research Institute

3.28 Task 28: Cable Tray Ignition at 500 ºC (FAQ 16-0011)

NUREG/CR-6850 uses cable damage temperature as a surrogate for cable ignition based primarily on experiments conducted by Sandia National Laboratories in the 1980s to 1990s. This is believed to result in overly conservative estimates of when fire will spread to involve entire cable trays. In fire PRA scenarios, cables within the flames from a fire are assumed to ignite and propagate the fire. Industry has submitted FAQ 16-0011 "Cable Tray Ignition" proposing to create a set of criteria for cable tray ignition. The proposed criteria are based on the assumption that only flame contact will result in cable tray ignition and the use of a low value for flame temperature of 500 ºC. While the proposal has some technical merit, additional research work needs to be conducted to ensure the values provide a reasonable level of conservatism. Testing, conducted as part of the cable coating project, has provided significantly more data on cable ignition criteria that can be used to evaluate the appropriateness of the FAQ. If the FAQ is accepted, propagation of cable tray fires will not be considered if the closest cable tray is more than 4 feet from the exposure fire.

Deliverables:
Support for Resolution of the FAQ

Schedule:
Documentation to Support Closure Memorandum Third Quarter 2018

Collaborators:
National Institute of Standards and Technology
Electric Power Research Institute

3.29 Task 29: NUREG-2180 Enhancement using Operating Experience (FAQ 17-0012)

Operating Experience (OE) was used to meet certain project objectives for NUREG-2180 in the areas of human reliability analysis, system availability and reliability, and system response to common products of combustion applicable to nuclear power plants (NPPs). While not a specific project objective, OE was also used in NUREG-2180 to estimate the duration of the incipient stage and frequency of a potentially challenging fires having an incipient stage of sufficient duration.

Industry proposed and event tree for quantifying the risk benefit of very early warning fire detection system (VEWFDS). NRC identified several serious faults with the methodology:

crediting limited, possibly irrelevant, data for human intervention rather than HRA methods, using non-suppression methodology to credit prevention, and directly using Appendix L, rather than a method like Appendix L, beyond its intended application. In addition, NRC felt there was inadequate technical justification for: changing the incipient stage threshold without collecting data (Appendix G of NUREG-2180), assuming the alarm occurs prior to the start of the fire, establishing the incipient stage duration and the time available, and using the main control room (MCR) non-suppression probability for area-wide applications.

Industry has submitted a revised proposed event tree for quantifying the risk benefit of VEWFDS under FAQ 17-012. The proposal includes considerations for determining incipient event frequency and duration of the incipient stage. Section 6.5.1 of NUREG/CR-6850 provides guidance for treatment of unique ignition source types that are not reflected in the generic frequency model ignition source list. Incipient events would only be considered when attributed to a monitored component and terminated either by actual fire or by intervention prior to fire. When an incipient event is terminated by intervention prior to fire, the characteristics (e.g., low-energy, temperature relative to ignition threshold) of the specific component should be considered to assign a partial count reflecting the likelihood of the incipient event progressing to an actual fire. When an incipient event is terminated by fire or by intervention (if partially counted), the characteristics of the surroundings (e.g., contents of affected cabinet) should be considered to classify the event into a fire severity group (e.g., challenging, potentially challenging). Given the lack of available information, NUREG-2180 acknowledged expert elicitation as one approach to develop a consensus or community opinion. The expectation is that a consensus or community opinion would result in a significantly longer incipient stage duration. For application to a particular ignition source, the most realistic duration of the incipient stage would be a composite distribution based on the number, types, and failure modes of associated components.

Going forward, industry proposes to collect VEWFDS data comparable to Appendix G in several areas:

- Application
    - Number and type of ignition sources (e.g., BIN 15 or BIN 4) for which VEWFDS is credited
    - Number and type of components comprising the ignition source
    - Capable of being de-energized at the panel or component level
- Administrative control in place to support a response
    - Level of detail in procedures
    - Roles of responsible personnel (e.g., decision maker)
    - Pre-stage equipment
- Operating experience
    - Defining t(end) based on t(de-energize) is misleading

The results will analyzed and reported in an EPRI document that identifies incipient event frequency and incipient stage duration. A process for maintaining and periodically updating the incipient results will be established.

Deliverables:
Support for Resolution of the FAQ

Schedule:

Documentation to Support Closure Memorandum Third Quarter 2018

Collaborators:
Electric Power Research Institute

3.30 Task 30: Improved HEAF Non Suppression Probability (FAQ 17-0013)

The non-suppression probabilities (NSP) for high energy arcing fault (HEAF) fires provided in NUREG/CR-6850 Supplement 1 (FAQ 08-0050) and NUREG 2169 are considered conservative. Fire event durations used for NSP extend past the control point in the fire event. As a result, the risk associated with HEAFs in critical fire areas may be artificially high. A review of licensee event reports (LERs) was conducted to assess whether HEAF non- suppression probability (NSP) guidance per NUREG/CR-6850 and NUREG-2169 is overly conservative. HEAF fire durations were reviewed to determine the time when the fire was considered to be controlled (i.e., when fire spread has been arrested, the zone of influence (ZOI) has reached its peak and when the threat of further damage, or hot gas layer was minimal). The time to control the fire is considered more relevant to potential damage impact than full extinguishment. Based on the analysis, five fire event durations were revised. Also during the review, two fire events were identified that were binned as electrical fires for NSP in NUREG-2169, but are HEAFs for ignition frequency. An additional event, fire event 162, included in EPRI's most recent FEDB is a HEAF event with a 46 minute duration.

Using the revised five HEAF fire durations, the other three HEAF events in NUREG 2169, and event 162 yields mean suppression rates 0f 0.029 including bus ducts and 0.024 when bus ducts are excluded. The original values from NUREG/CR-6850, NUREG/CR-6850 Supplement 1, and NUREG-2169 range from 0.011 to 0.013. The Organization for Economic Co-operation and Development (OECD) report, Fire Project Topical Report No. 1 "Analysis of High Energy Arching Fault (HEAF) Fire Events," incorporates data from HEAF events in 10 countries (not including the USA). The OECD average duration of HEAF events outside the US was 31.3 minutes. The OECD average duration of HEAF events, both US and International is 32.7 minutes. FAQ 17-0013 proposes an average duration of 35 min (41.89 w/o Bus Ducts), which is conservative with respect to the international data.

For the HEAF events in the database, a new average time to suppression of 35.0 (41.89) minutes is recommended. It is being argued that the fire is controlled early on, and propagation to trays had either burned out or this portion of the fire had been extinguished successfully earlier on. Thus, in PRAs, the longer duration HEAF scenarios, which may lead to hot gas layers (HGLs), etc. are much more likely in line with an electrical cabinet, or cable fire NSP curve. Therefore, the HEAF fires that are evaluated at time periods well beyond the HEAF itself (i.e., 20 minutes) should use the electrical cabinet or cable tray NSP and lambda mean value. It is proposed that the mean suppression rate be increased by approximately a factor of two (from 0.013 to 0.024 (0.029)) to reflect the revised average fire duration for HEAFs originating in high energy equipment in the US.

Deliverables:
Support for Resolution of the FAQ

Schedule:
Documentation to Support Closure Memorandum Third Quarter 2018

Collaborators:
Electric Power Research Institute

3.31 Task 31: HEAF Event Frequency 1E/non-1E

HEAF events are modeled using Appendix M of NUREG/CR-6850. The model guidance is based on operating experience from an event at San Onofre Nuclear Power Station Unit 3 from 2001. Any vulnerable component within 3' horizontally is assumed to suffer physical damage, and the first overhead cable tray will be ignited if within 5' vertical distance and 1' foot vertical distance from the top of the cabinet. The ensuing fire is assumed to reach the peak HRR immediately with no t^2 ramp up. The model does not differentiate between ignition sources.

Review of Operating Experience suggests that the classification of the electrical device plays a significant role in the potential for a HEAF event. Class 1E equipment has had fewer HEAF events compared with Non-Class 1E equipment. In order to improve realism, it is suggested to develop a methodology that addresses the differences between Class 1E and Non-Class 1E electrical equipment. Class 1E equipment is subject to higher maintenance and inspection standards and as such common precursors to HEAF events are ameliorated prior to a HEAF event occurring. An overall split-fraction that differentiates the source of the HEAF events can be generated using operating experience. This would result in the following:

- Class 1E Split Fraction –0.21
- Non-Class 1E Split Fraction –0.79

Deliverables:
Documentation of FAQ Resolution

Schedule:
FAQ Closeout Documentation First Quarter 2020

Collaborators:
Electric Power Research Institute

3.32 Task 32: Plant Trip Probability

Fire PRAs assume every fire leads to a plant trip, when in actuality it is dependent on the ignition source and severity of fire. Guidance is needed for applying a conditional probability of plant trip following a fire event.

Deliverables:
Documentation of FAQ Resolution

Schedule:
FAQ Closeout Documentation First Quarter 2020

Collaborators:
Electric Power Research Institute

3.33 Task 33: Updated Electrical Cabinet Non Suppression Probability (NSP) Curve

Industry believes there is a disconnect between the average duration of fire scenarios in fire PRAs and fire event experience. The fire durations can have time lags or delays associated with reporting which inflates the fire time. Delays in declaring a fire event extinguished are associated with de-energizing equipment, offsite fire brigade, and water application. Time to control is believed to be a better data point for plant response and risk/damage assessment. To support development of more realistic fire event duration, NRC event reports, LERs, and other sources of event information will be reviewed to identify when fires are controlled, rather that extinguished to refine the NSP calculations.

Deliverables:
Documentation of FAQ Resolution

Schedule:

FAQ Closeout Documentation	First Quarter 2020

Collaborators:
Electric Power Research Institute

3.34 Task 34: Fire Damages Only Part of Equipment in Cabinet

All trains and functions that can be affected by a fire are assumed to occur at the cabinet ignition frequency. For most cabinets, this is believed to be a mildly conservative assumption (e.g. breaker goes open/breaker goes closed). For cabinets that control multiple trains from different power supplies, this can be overly conservative. Industry events of cabinets with multiple trains do not show loss of all trains (e.g. single alarm card damaged while others are still functional, single HS malfunction, etc.).

For an uninformative prior approach, assume each possibility has an equal likelihood of occurrence. For simplification, the impact option should be grouped by train. A train is defined as any equipment in the cabinet powered from the same ultimate external power supply to the cabinet. If all equipment in the cabinet is powered from the same external source, then this method would not be applicable. This would only apply to scenarios with no external damage. If the fire is large enough to damage external equipment, then larger internal losses are expected.

Deliverables:
Documentation of FAQ Resolution

Schedule:

FAQ Closeout Documentation	First Quarter 2020

Collaborators:
Electric Power Research Institute

3.35 Task 35: Reduce NSP Floor from 1E-3 to 1E-5

The non-suppression probability (NSP) floor is at 1-in-1000 for an infinite duration fire. This can be a significant contributor to control room abandonment likelihoods with lower heat release rate scenarios. The recommendation is to change the floor to 1E-5. The fire brigade composition and method of operation is similar to a reactor operational response crew. There is a leader directing the actions of the fire brigade members. The leader will bring more and more resources to bear as the scenario progresses. The largest benefit is a reduction in the control room abandonment likelihood. By the time the floor is reached, the room will already be lost due to a damaging hot gas for most other types of fires.

Deliverables:
Documentation of FAQ Resolution

Schedule:

FAQ Closeout Documentation	First Quarter 2020

Collaborators:
Electric Power Research Institute

Ongoing Work: Miscellaneous Support

3.36 Task 36: NRC-RES/EPRI Fire PRA Training

RES and EPRI jointly issued NUREG/CR-6850 (EPRI 1011989), "Fire PRA Methodology for Nuclear Power Facilities," in September 2005. The report documents state-of-the-art methods, tools, and data for conducting a fire probabilistic risk assessment (PRA) in a commercial nuclear power plant (NPP). Although not required by NFPA 805, development of a quality fire PRA can support the performance-based aspects of the NFPA standard. The Fire PRA Methodology consolidated existing state-of-the-art methods, and in many areas developed new methods advancing the state-of-the-art. In addition, the methodology presented in NUREG/CR-6850 and supplementary documents can be used for risk-informed, performance-based approaches outside of NFPA 805 applications to support general risk insights and fire protection regulatory decision making.

To effectively communicate the methods presented in NUREG/CR-6850, RES and EPRI conducted a joint public workshop for about 80 attendees at the EPRI Nondestructive Evaluation (NDE) Center in Charlotte, NC from June 14–16, 2005. Since then, workshops and formal training have been provided jointly by NRC staff, NRC contractors, and EPRI representatives. The benefits of these training sessions were identified as necessary training to allow inspectors to meet qualifications. As such, a partial requirement of the NRC inspector advanced fire protection qualification program includes attending all five modules (fire PRA, circuit analysis, fire hazards, fire human reliability analysis, and advanced fire modeling).

RES in cooperation with EPRI will provide training in the methods presented in NUREG/CR-6850, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities," and subsequent documents that supersede the guidance contained in NUREG/CR-6850. RES and EPRI will conduct the training sessions in an open forum such that members of the public, licensees, regional inspectors, and NRR fire protection staff can attend.

The continuation of this training will support Inspection Manual Chapter (IMC) 1245, Appendix C-7, "Fire Protection Inspector Technical Proficiency Training and Qualification Journal", IMC 1245, Appendix D3, "Fire Protection Advanced-Level Training," and NRR "Grow Your Own" PRA Analyst Qualification Training Program.

Currently, NRC-RES/EPRI offer five modules of the Fire PRA Training:

- Module I: Probabilistic Risk Assessment (PRA)
- Module II: Electrical Analysis
- Module III: Fire Analysis
- Module IV: Human Reliability Analysis (HRA)
- Module V: Advanced Fire Modeling

Deliverables:
Conduct training course as needed

Schedule:
RES will coordinate with EPRI each year to provide training sessions, on-going.
The frequency and number of offerings my increase or decrease based on need.

Collaborators:
Electric Power Research Institute

4 LIST OF ACRONYMS

ADAMS	Agency-wide Documents Access and Management System
ANS	American Nuclear Society
ASME	American Society for Mechanical Engineers
ATHEANA	A Technique for Human Event Analysis
BNL	Brookhaven National Laboratory
BTP	Branch Technical Position
BWR	Boiling Water Reactor
CAROLFIRE	Cable Response to Live Fire
CDF	Core Damage Frequency
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
DESIREE-FIRE	Direct Current Electrical Shorting In Response to Exposure-Fire
DOE	U.S. Department of Energy
EPRI	Electric Power Research Institute
ET	Event Tree
FAQ	Frequently Asked Questions
FSAR	Final Safety Analysis Report
GI	Generic Issue
GIRP	Generic Issues Review Panel
GL	Generic Letter
HCLPF	High Confidence of Low Probability of Failure
HEAF	High Energy Arc Fault
HEP	Human Error Probability
HEPA	High Efficiency Particulate
HFE	Human Failure Events
HRA	Human Reliability Analysis
HRR	Heat Release Rate
IEEE	Institute of Electrical and Electronics Engineers
IN	Information Notice
INL	Idaho National Laboratories
LCO	Limiting Condition of Operation
LOC	Loss of Control
LOH	Loss of Habitability
LOOP	Loss of Offsite Power
LPSD	Low Power Shutdown
MCR	Main Control Room
MCRA	Main Control Room Abandonment
MOU	Memorandum of Understanding
NEI	Nuclear Energy Institute
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NPP	Nuclear Power Plant
NRC	U.S. Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation (NRC)
OL	Operating License
PSF	Performance Shaping Factor
PIRT	Phenomena Identification and Ranking Table
PNNL	Pacific Northwest National Laboratories

PRA	Probabilistic Risk Assessment
PWR	Pressurize Water Reactor
QA	Quality Assurance
RAI	Request for Additional Information
RES	Office of Nuclear Regulatory Research
RI/PB	Risk-Informed/Performance-Based
SAR	Safety Analysis Report
SCS	Supplemental Cooling System
SDP	Significance Determination Process
SNL	Sandia National Laboratories
SPAR	Standardized Plant Analysis Risk
SRM	Staff Requirements Memorandum
TR	Technical Report
TS	Technical Specifications
VAC	Volts of Alternating Current

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