June 21, 2012

Mr. Biff Bradley
Director, Risk Assessment
Nuclear Energy Institute
1776 I Street, NW, Suite 400
Washington, DC 20006

SUBJECT: RECENT FIRE PRA METHODS REVIEW PANEL DECISIONS AND EPRI 1022993, "EVALUATION OF PEAK HEAT RELEASE RATES IN ELECTRICAL CABINET FIRES"

Dear Mr. Bradley:

Thank you for your letters, dated September 27, 2011, through June 5, 2012, providing the series of recent Fire PRA Methods Review Panel Decisions on four methods used for analyzing fire risk contributions. A Nuclear Regulatory Commission (NRC) technical expert participated on this Panel and provided the NRC with continuous updates as to the status of Panel Decisions. Subsequently, the NRC has reviewed the Panel Decisions and established the four positions discussed in the Enclosure.

The NRC also received a final copy of EPRI 1022993 and provided results of a post-publication review by the Office of Nuclear Regulatory Research to Mr. Ken Canavan, Director, Plant Technology, Nuclear Sector, Electric Power Research Institute (Agencywide Documents Access and Management System (ADAMS) Accession Numbers ML121510215 and ML121510220). As a result of this review, the NRC has also established a position on the use of this method that is included in the Enclosure.

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We welcome further dialogue on these topics in the mutual effort to enhance analytical methods for use in fire PRA regulatory applications. If you have any questions regarding the NRC staff positions on the four analysis methods used for fire PRAs or EPRI 1022993, please feel free to contact me.

Sincerely,

/RA/

Joseph Giitter, Director
Division of Risk Assessment
Office of Nuclear Reactor Regulation
US Nuclear Regulatory Commission

ENCLOSURE:
As stated

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DATE	06/21/2012	06/21/2012	06/21/2012

OFFICIAL RECORD AUTHORITY

RECENT FIRE PRA METHODS REVIEW PANEL DECISIONS AND EPRI 1022993, "EVALUATION OF PEAK HEAT RELEASE RATES IN ELECTRICAL CABINET FIRES"

1. Frequencies for Cable Fires Initiated by Welding and Cutting

On October 7, 2011, NEI submitted a letter on "Recent Fire PRA Methods Review Panel Decision: Frequencies for Cable Fires Initiated by Welding and Cutting." As stated in the NEI letter, "The panel determined that the updated frequencies in the proposed method were technically justified and were acceptable for use in FPRAs." The NRC has reviewed the panel resolution, including discussion with the NRC panel representatives, and endorses use of this method as resolved by the panel via that letter.

2. Clarification for Transient Fires

On September 27, 2011, NEI submitted a letter on "Recent Fire PRA Methods Review Panel Decision: Clarification for Transient Fires and Alignment Factor for Pump Oil Fires." As stated in the NEI letter, "For the first method, which dealt with heat release rates for transient fires, the panel determined that the method provided an approach that could be applied to support different heat release rates for modeling of transient fire scenarios." The NRC has reviewed the panel resolution, including discussion with the NRC panel representatives, and endorses use of this method as resolved by the panel via that letter with the following changes in the first bulleted clarification to ensure the intent is more fully understood:

> *The presence of a transient combustible fuel package by itself is not expected to result in a fire event in the absence of an ignition source, although the possibility of an ignition source cannot be dismissed. It should be noted that ~~As such,~~ the mass of such a package by itself need not be used as the sole determinant for the characteristics of a postulated fire event. ~~However, it~~ It is acknowledged that in some circumstances, ~~the two~~ an ignition source and combustible fuel package may co-exist as the result of a single work activity.*

3. Alignment Factor for Pump Oil Fires

On September 27, 2011, NEI submitted a letter on "Recent Fire PRA Methods Review Panel Decision: Clarification for Transient Fires and Alignment Factor for Pump Oil Fires." As stated in the NEI letter, "The second method, which involved characterization of pump oil fires in fire PRAs, was also found to be technically acceptable with one limitation." The NRC has reviewed the panel resolution, including discussion with the NRC panel representatives. While agreeing philosophically with the approach, the NRC has revisited the specific details of the technical review based on a question regarding the data supporting the method. The NRC notes that, while it was expected that the original panel resolution would be revisited in light of the NRC question, this process was not completed. Nonetheless, the insights the panel did provide in the early phases of this suspended effort have been incorporated in Attachment 1, which represents the modification of the panel resolution method that the NRC endorses for use.

Enclosure

4. Electrical Cabinet Fire Treatment Refinement Details

On June 5, 2012, NEI submitted a letter on "Recent Fire PRA Methods Review Panel Decision: Treatment of Electrical Cabinets." As stated in the NEI letter, "The panel collectively determined, with one dissenting opinion, that this method can be used in Fire PRA in certain circumstances." Unlike the previous three methods, the NRC representative dissented on the use of this method. The NRC has reviewed the panel resolution, including discussion with the NRC panel representative, and agrees with the dissent. A modified version of this dissent, as an NRC position, is provided in Attachment 2. Based on this dissent, the NRC does not endorse this method for risk-informed, regulatory applications, including NFPA 805 applications.

5. EPRI 1022993 – "Evaluation of Peak Heat Release Rates (HRRs) in Electrical Cabinet Fires"

At the NEI Fire Protection Information Forum in September 2009, Hughes Associates presented a preliminary approach by which experimental results might be combined with detailed fire modeling to estimate HRRs from electrical cabinet fires considering varying degrees of ventilation. This was offered as a possible enhancement to the more generic HRRs provided in NUREG/CR-6850 (EPRI 1011989) for electrical cabinet fires. EPRI, in conjunction with SAIC, developed this preliminary approach into EPRI 1022993, published in February 2012. At the time of the original presentation by Hughes Associates, NRC-RES indicated its intention to delay any experimental program on electrical cabinet fires in lieu of the EPRI-SAIC effort, with the expectation that the methodology would be final within a year. Ultimately, this publication took over two years to produce. NRC was given an opportunity to perform a limited review of a draft of what was intended to be the final report in mid-2011, but was able only to provide preliminary comments, with the understanding that another opportunity for detailed review would be provided prior to final publication. However, this was not provided, and the report was published as final in February 2012.

Subsequently, NRC-RES has performed the detailed review originally intended prior to final publication. The results of this review are provided in Attachment 3. In summary, it appears that additional work beyond a simple rewriting of the published document is necessary to adequately address the concerns raised as a result of this review. Further, the NRC believes that significant additional data are required to develop improved guidance on electrical cabinet HRR. Such data are unlikely to be found in available literature. In an effort to improve the HRR information in NUREG/CR-6850 (EPRI 1011989), NRC-RES will restart the effort to conduct additional fire testing of electrical cabinets. This effort will identify, obtain, and test electrical cabinets representative of those currently used in nuclear power plants. NRC-RES plans to interact closely with all stakeholders on this effort. Based on the NRC concerns raised on the EPRI 1022993 final report and pending the NRC-RES experimental test results, the NRC does not endorse this method for risk-informed, regulatory applications, including NFPA 805 applications.

Refined Treatment of Oil Pump Fires from NUREG/CR-6850

(Pumps of Smaller Oil Capacity than Main Feedwater Pumps)

NUREG/CR-6850 proposed a technique for assigning likelihoods to postulated sizes of oil spills from a pump. Specifically, the likelihood of 0.98 was assigned to an oil spill of 10% of the capacity of the pump, and the likelihood of 0.02 was assigned to an oil spill of 100% of the capacity of the pump. This was the only approach for pump oil spills documented in NUREG/CR-6850.

In FAQ 44, NRC and industry refined this NUREG/CR-6850 treatment for oil fires for main feedwater (MFW) pumps. A review of events from the EPRI fire events database (FEDB) confirmed that no events demonstrated a 10% or 100% oil spill given the very large capacity of oil in such pumps (up to 1000 gallons). However, analysis techniques produced small values for the likelihood of 10% and 100% oil spills of MFW pumps.

The following study has been done to review the operational experience for oil fires from pumps with smaller oil capacities than MFW pumps. If appropriate, this study will adjust the likelihood of 10% and 100% oil spills from generic pumps, as well as the likelihood that damage is confined to the pump from an oil fire. Oil spills of 10% to100% capacity are treated as oil pool fires of the respective capacity for purposes of fire PRA modeling.

The process to perform this study and update the likelihood of fires from oil spills follows:

1. Review oil pump fires from the EPRI fire events database identified in NUREG/CR-6850. Note that fires characterized as electrical fires in NUREG/CR-6850 were not re-examined for this issue.

2. Determine if the fire event showed characteristics or fire protection response indicative of an oil pool fire. An example of a fire protection response of this nature is an automatically actuated fixed suppression system. Note that simple oil soaked insulation fires that do not propagate are not examples of fires that could be characterized as oil pool fires.

3. Establish if these fires result from 10% or 100% of the pump's capacity. Note that other size spills were not considered for this simplified model; thus, these two spill sizes cover the entire spectrum of spills that produce damage beyond the pump. Also, it must be established whether this fire merits full weight (1) in this approach, or if the fire is so uncertain as to merit only a weight of 0.5 fire.

4. Develop the ratio of oil spills of 10% (or 100%) pump capacity to all oil pump fires to determine the probability of these particular spills.

Qualitative Aspects of Solution

After a review of the oil fire events from pumps (excluding MFW pumps), five candidates for oil spill fires of 10% capacity or greater were identified. Those fire events correspond to incident numbers 159, 444, 495, 566, and 714 in the EPRI FEDB. After review of the

NFPA FAQ 08-0050 solution documented in NUREG/CR-6850 Supplement 1, it was determined that event number 495 was not an oil fire. FAQ 50 specifies that event number 495 is the same event as event 914, and that the event is an electrical fire. Thus event number 495 is removed from consideration as a 10% or greater capacity oil spill fire as well as an oil fire for a pump.

A special consideration was attributed to event numbers 159 and 224. NUREG/CR-6850, EPRI TR 1011989, provides the following description for the pump fire ignition source bin (see Volume 2, Pg. 6-18):

> "Bin 21 – Pumps (Plant-Wide Components) and large hydraulic valves: For this methodology, it is assumed that above a certain size, fire ignition is the same for all pumps. Pumps below 5 hp are assumed to have little or no significant contribution to risk. Do not count small sampling pumps. The number of pumps in all plant locations defined as "Plant-Wide" should be estimated.
>
> *Due to a lack of sufficient statistical data, a separate bin was not defined for large valves that include hydraulic fluid powered mechanisms. It is recommended such valves (e.g. Main Steam Isolation Valves, and Turbine Stop Valves) be counted and included in the pump bin.*"

Fire events 159 and 224 are examples of failures of large hydraulic valves being referred to in the second paragraph of the Bin 21 description. In fire event 159, oil was deposited on hot steam pipes due to a rupture of hydraulic oil lines associated with the sudden closure of the steam generator stop valves. Due to personnel error, the hydraulic oil had been mixed with diesel generator fuel, and resulted in fires in two separate locations within containment. This rupture apparently led to a major spill and fire since several hose streams were applied for extinguishment. Event 224 is also a large hydraulic valve event, but only produced small fires from the oil leak.

Given that fire events 159 and 224 are associated with valve control hydraulic lines rather than a pump, these events were also removed from treatment for general pump fires. The original guidance recognized that fires involving hydraulic valves would be unique, but due to a lack of data, grouped the hydraulic valve events in with the pump ignition source bin. Hence, these events have been eliminated from the pump fire set for the purposes of this analysis. (see the final section of this document for further discussion).

The following is a description of the remaining three events and justification that they be treated as either 10% or 100% oil spill fires for this issue. Each of these events were categorized as potentially challenging events in the calculation of fire ignition frequency for oil pump fires in bin 21 in NUREG/CR-6850.

Fire Event 444

According to the description of fire event 444, five-foot flames shot above the component cooling water (CCW) motor. The fire lasted for five minutes. The fire is classified as an oil fire since an electrical fire alone would not produce such flames; this was not just an insulation fire as the event description indicates. It appears likely that oil leaked into the motor from the motor/pump interface bearings, vaporized, and ignited. Although this fire did not actuate the fire

detection system/suppression system and eventually self extinguished, a fire of this magnitude can only be modeled in PRA as an oil spill fire. This oil fire is expected to result from a smaller oil spill since a large amount of oil would likely have burned longer than 5 minutes. A relatively small amount of vaporized oil could have produced such a flame, but the five-minute fire duration implies a substantial quantity of oil was involved. Given that a typical CCW pump has an oil capacity of 1 to 10 gallons and the stated five-minute fire duration, the oil spill size for this event is estimated as 10%. Thus this fire is assigned full weight at 10% of the oil capacity.

Fire Event 566

According to the description of fire event 566, an upper bearing oil sight glass on a shutdown cooling pump broke and leaked oil, leading to an oil fire. Information is scant on this event; however it is known that the fire was extinguished by the plant fire brigade with a portable CO2 extinguisher. Damage from this fire was between $5K and $50K. The time for suppression was listed as 25 minutes.

The size of the leak from the broken site glass is uncertain. The leak could have been large or small, depending on the extent of the break. If the sight glass had broken entirely, a relatively high rate of leakage flow could result whereas a crack in the sight glass could have resulted in very slow oil leakage. The event does not specify the size of the break. On one hand, the 25 minute lengthy suppression time might be indicative of a larger spill and more extensive fire. Yet, it may represent successive suppression attempts due to many reflashes of a relatively small fire fed by a slow but ongoing leak.

The oil capacity of this pump is estimated to be 1 to 10 gallons. Given the uncertainty, this fire receives a weight of 0.5 fire. Absent any other signs of a potentially major spill, this event is assigned a 10% oil spill.

Fire Event 714

According to the description of fire event 714, an upper bearing seal failure in a heater drain pump failed and produced an oil fire. The signature of this event is major, with a fixed wet pipe suppression system actuating, and dry chemical extinguishers and a hose stream applied. Damage from the fire was between $100K and $500K. The fire duration was listed as 15 minutes, and suppression time was 5 minutes. The capacity of a typical pump of this type is estimated between 1 and 10 gallons of oil.

The primary signature of this fire is the actuation of the wet pipe sprinkler system, follow-up fire-fighting by the fire brigade using manual hose streams, and the extent of damage. These factors are indicative of a larger and more extensive fire almost certainly associated with more than one gallon of oil. It cannot be stated with certainty that the size of the oil spill was close to 100% of the capacity, but it likely much larger than 10%. As a result of the simplicity of the model and the uncertainty of the actual spill size as derived from the description in the database, this fire is treated as a 100% oil spill fire. This treatment may be conservative; however, with the level of detail in the database, such a treatment is warranted.

As a result, this fire receives full weight and is estimated at 100% oil capacity.

Quantitative Aspects of Solution

NUREG/CR-6850 identified 24 oil fires from pumps for the fire ignition frequency for pumps from oil. Three fires have been removed from the set; thus, 21 fires now constitute the set of oil fires for general pumps, excluding fires from failures of large hydraulic valves, and will be used in the denominator to establish the likelihood of fires of a certain spill size.

From the discussion above, all but 2.5 fires produced damage limited to the pump itself. 1.5 fires constitute pump fires with oil spills of 10% of the capacity of the pump. One fire constitutes an oil spill of 100% capacity.

As a result, the following likelihoods and oil spill sizes should be attributed to pumps generically when evaluating bin 21 for oil fires from pumps.

1. 18.5/21 (about 88%) of oil fires from pumps limit damage to the pump itself

2. 1.5/21 (about 7%) of oil fires from pumps produce oil pools of 10% capacity

3. 1/21 (about 5%) of oil fires from pumps produce oil pools of 100% capacity

Since bin 21 contains two component types that have now been separated for this approach, pumps and large hydraulic valves must be treated as separate fire initiators. Combining these two distinct initiators in the analysis will lead to complications not accounted for in this approach. To address this concern, a pump and a large hydraulic valve should be analyzed separately as ignition sources.

A Final Note Regarding Large Hydraulic Valves

As noted above, the oil spill size split fractions cited above are not applicable to hydraulic mechanisms such as large hydraulic valves. These valves are counted among the population of fire ignition sources included in Bin 21. Thus, the calculation of fire ignition frequency for these valves is unchanged and calculated according to NUREG/CR-6850. For a large hydraulic valve, all fires are oil fires. To characterize the fire scenarios for oil spill size and their respective likelihoods, the original NUREG/CR-6850 approach outlined for the treatment of oil fires (i.e., 98% of oil spills involve 10% of the oil and 2% of oil spills involve 100% of the oil) should be applied.

UNREVIEWED ANALYSIS METHODS PANEL DECISION ON THE ERIN METHOD

The NRC does not agree with the Unreviewed Analysis Methods panel decision on the ERIN method for use of a "propagation probability" to estimate the likelihood of fires in electrical cabinets (including low voltage, motor control centers, load centers and switchgear) spreading beyond the cabinet if not suppressed and automatically damaging the nearest cables. The bases for not accepting the panel decision are the following.

The first concern is a practical consideration. The NRC, through its panel participation, had been aware since the start of the panel review of this method that there were at least two additional methods, one quite diverse from the other two (see Item 5 in main text), proposing to address this same phenomenon that were then currently under development and soon to have been available for review. As the NRC representative stated at the original meeting, he believed that all three methods should have been reviewed concurrently to determine the strengths and weaknesses of each, in lieu of a sequential review where the first would be done without knowledge of the second or third and the second without knowledge of the third. While all three may have ultimately proven acceptable, there was a concern that reviewing sequentially could prompt a "myopic" and premature decision, especially on the first approach, and to some extent on the second. Ultimately, the panel might have approved (or rejected) a method that might in hindsight have merited the opposite decision.

The second concern is a technical consideration. The ERIN approach, using a single "factor," blends together all the case-specific phenomena that contribute to growth of a fire within an electrical cabinet and then assigns an "average" or "aggregate" propagation probability on a generic basis for igniting the first cable tray. Thus, important case-specific conditions such as combustible loading within the cabinet (and the associated heat release rate [HRR] profile with zone of influence), fire location within the cabinet, fire growth profile, ventilation of the cabinet, distance from the cabinet (or fire) to the nearest cables, types of cables (e.g., thermoset or thermoplastic), are not treated. An alternate method had been proposed by EPRI/SAIC, which employs a more phenomenological model, coupled with analysis of results from experiments, as an enhancement of the process discussed in NUREG/CR-6850 (EPRI TR-1011989) for estimating propagation probability of fires beyond electrical cabinets. While the draft version of this method was reviewed at a high-level by NRC staff, but returned for further development, it appeared more consistent with the philosophy established in NUREG/CR-6850 (EPRI TR-1011989) of developing propagation probability as an independent "factor" relative to ignition or suppression.[1]

If the various types of electrical cabinet fires are combined into one group, as in NUREG/CR-6850 (EPRI TR-1011989) (pre-Supp. 1), the method proposed by ERIN yields a

[1] Note that the perspective in Attachment 2 regarding the EPRI/SAIC method is one of an historical nature, indicating the NRC panelists' perception while the ERIN method was being reviewed. As discussed in Item 5 in the main text, despite only a preliminary review of the EPRI/SAIC method and limited feedback, the NRC expected most of its concerns with the draft to have been resolved prior to final publication, with an opportunity for a detailed review of the final before publication. This did not occur. As discussed in Item 5 in the main text, despite the perhaps optimistic expectations of the NRC panelists for the EPRI/SAIC method during the ERIN method review, this has not proven to be the case, i.e., the final EPRI/SAIC method does not reach the NRC panelists' original expectations.

propagation probability, implicitly crediting suppression, of ~0.15.[2] It is expected that the "standard" assumptions from NUREG/CR-6850 (EPRI TR-1011989), when combined with enhanced fire modeling, may produce defensible, phenomenologically-based results of comparable utility for fire PRA applications. Such would eliminate the need even for a "factor" approach, which may not meet more than Capability Category (CC) I of Part 4 of ASME/ANS RA-Sa-2009, or fail to achieve "Met" if there is no distinction among the CCs, in particular the following Supporting Requirements (for CC-II, the level typically considered "acceptable" for risk-informed applications):

1. FSS-C1, which requires at least a two-point HRR model for damaging fires;

2. FSS-C2, which requires that both fire intensity and duration be accounted for when assigning characteristics to the ignition source;

3. FSS-C3, which requires treatment of fire stages including growth and burnout;

4. FSS-C4, which requires that any severity factor remain independent of other quantification factors (e.g., suppression);

5. FSS-C6, which requires an assumption that target damage occurs when the exposure environment exceeds the damage threshold;

6. FSS-D3, which requires use of fire modeling tools that provide reasonable assurance that the fire risk of any physical analysis unit that represents a significant contributor is bounded or realistically characterized;

7. FSS-E3, which requires that a mean value and statistical representation of the uncertainty intervals for parameters used to model significant fire scenarios be provided.

Historically, an attempt to develop a similar type of "factor" was pursued during the development and resolution of Frequently Asked Question (FAQ) 08-0042. At least one of the original authors of NUREG/CR-6850 (EPRI TR-1011989) participating in this NRC-industry consensus effort noted that the fire frequencies developed from the FEDB were for challenging (self-sustaining) fires, such that an "electrical cabinet fire propagation factor," being proposed by the industry, would already have been incorporated, at least loosely, leaving no need for any additional "propagation factor." Propagation was not so much the issue as was HRR. Furthermore, the effect of such propagation may already have been addressed in aspects of the fire risk "equation" beyond the frequencies, such as HRRs and non-suppression probability. As agreement among the technical experts could not be reached, the FAQ was resolved without inclusion of any discussion as to a potential factor.

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2 Note two particular dissents by the NRC panelists with the "weights" assigned to two FEDB events by the Panel: (1) Event 236, weighted as "non-aggressive" (0) by the Panel, but 0.5 ("somewhat aggressive") by the NRC panelists; (2) Event 352, dismissed from the count altogether ("count weight" = 0) and, by default, therefore "non-aggressive" by the Panel, but 0.5 for both "count weight" and "aggression" by the NRC panelists. (If both of these were weighted as suggested, the "factor" would increase slightly from ~0.15 to ~0.17.)

ATTACHMENT 3

Agencywide Documents Access and Management System (ADAMS)
Accession Numbers:

ADAMS Accession No.: ML121510215 - Letter from R. Correia to K. Canavan Re: NRC Review of EPRI TR-1022993, “Evaluation of Peak Heat Release Rates in Electrical Cabinet Fires”.

ADAMS Accession No.: ML121510220 - NRC Comments on EPRI TR-1022993, “Evaluation of eak Heat Release Rates in Electrical Cabinet Fires”.