Data Collection in Support of Integrating Operating Experience into NUREG-2180

Purpose

At the October 3-5, 2017 NRC/Industry workshop on improving realism in Fire PRAs, an event tree (Attachment 1) for quantifying the risk benefit of in-cabinet Aspirating Smoke Detection (ASD) Very Early Warning Fire Detection Systems (VEWFDS), incipient detection, was proposed as an alternative to the event tree in Figure 6-4 and Figure 6-6 in NUREG-2180. The proposed event tree was based on two key parameters (i.e., the incipient event frequency and the incipient stage duration) for which adequate knowledge does not currently exist. Also at this workshop, an industry initiative was proposed to collect the data necessary to establish adequate knowledge for using these two key parameters. This whitepaper provides additional details about:

1) What data will be collected and why that collection is necessary,
2) How the data will be collected and what length of time is this collection effort expected to take, and
3) How will the data be used in the proposed event tree?

Background

The greatest risk benefit of the VEWFDS comes from having an opportunity to address a developing fire situation prior to the occurrence of an actual fire. However, to model a prevention strategy, operating experience alone is inadequate to establish an incipient event frequency or an incipient stage duration. In particular, the more aggressively the prevention strategy is pursued, the less evidence exists for when, or even whether, an actual fire would have occurred. Instead of abandoning the prevention strategy to improve the state of knowledge, VEWFDS operating experience must be subjected to some informed judgment to establish an incipient event frequency and an incipient stage duration, with consideration for the resulting additional uncertainty.

In proposing a more realistic treatment of VEWFDS operating experience by the Fire PRA, there is no suggestion that the plant should diminish the response to a VEWFDS ALERT/ALARM. In particular, the plant must continue to respond aggressively to every VEWFDW ALERT/ALARM as if fire is imminent and allow the Fire PRA to model the resulting operating experience as appropriate.

Review of Components Identified in Reportable Fire Events

As described in Section 2.2 of NUREG-2180, not all situations involving an incipient stage actually result in a fire. But, those situations that are similar to other situations identified in reportable fire events could reasonably be considered more likely to result in a fire. Therefore, a review of the Reportable Fire Events in the INPO ICES database to identify the initiating component would better inform efforts to establish an incipient event frequency and an incipient stage duration. Attachment 2 provides some preliminary results of this incomplete review.

During the review, events would be screened to ensure that the identified components remain relevant to the intended purpose. For Phase I, the effort would focus on components inside low-voltage ($\leq$250V) control cabinets. For Phase II, the scope of this effort may (or may not) need to be revisited to cover the range of ASD VEWFDS applications. As the review progresses, additional screening criteria may be needed. For example, an event involving changing a light bulb mounted on the outside of a panel would

be screened, unless the report provided some indication that the event involved the interior of the cabinet. Any additional screening criteria would be documented and justified relative to the stated objective.

Incipient Event Frequency

In the proposed event tree (Attachment 1), the incipient event frequency was used for the initiating event. The collection of data is necessary to establish the incipient event frequency because fires in electrical enclosures credited with VEWFDS are not well-represented by the generic BIN 15 ignition frequencies, due to physical and administrative differences in the as-built and as-operated plant. Physically, VEWFDS is installed selectively, rather than uniformly or randomly, in electrical enclosures (usually low-voltage) based, in part, on expectations for effectiveness. Administratively, the response to VEWFDS ALERTs and VEWFDS ALARMs represents an operational difference in the treatment of the electrical enclosures for which VEWFDS has been credited with the intent of preventing an actual fire. Consequently, electrical enclosures with in-cabinet ASD VEWFDS are considered unique ignition sources.

Section 6.5.1 of NUREG/CR-6850 provides guidance for establishing a fire frequency for unique ignition sources that may not be reflected in the generic frequency model ignition source list. In particular, the following information should be collected:

1) Characterization of the ignition source (e.g., power, voltage),
2) Percentage of time the ignition source is functioning when it has the potential of starting a fire,
3) Any history of fire events in the plant associated with the specific ignition source, and
4) History of fire events at nuclear and non-nuclear locations.

The incipient event frequency will be determined from a review of operating experience. Either a fire in an electrical enclosure credited with VEWFDS or certain occurrences where a VEWFDS ALERT/ALARM was terminated by intervention prior to actual fire would be considered an incipient event. Intervention requires a physical change to alleviate the problem not merely efforts to identify the affected component. A VEWFDS ALERT/ALARM that clears without intervention and does not progress to an actual fire would not be considered an incipient event. Data will be considered only for ignition sources credited with in-cabinet VEWFDS. Fire or intervention in an electrical enclosure where VEWFDS was not credited would not be considered an incipient event, even if the event caused a VEWFDS ALERT/ALARM.

With respect to the incipient event frequency, an actual fire in an electrical enclosure credited with VEWFDS would be counted, as described in Section 3 of NUREG-2169. Actual fires are classified as challenging (CH), potentially challenging (PC), undetermined (U), or non-challenging (NC). Fire events classified as undetermined are counted as half and those classified as non-challenging are not counted.

The most realistic treatment of incipient events terminated by intervention prior to an actual fire would be to classify them as non-challenging and not count them. This treatment would also be most consistent with NUREG-2169, in which the non-challenging classification already includes incipient events such as "fires that remained in a smoldering state with no apparent potential for open flaming" and "component overheating incidents with light or moderate smoking but without any flaming." Even the classification of fires "involving ignition of the component followed by self-extinguishment without

any required intervention" as non-challenging does not create any inconsistency with intervention as part of a prevention strategy, because NUREG-2169 is clearly using intervention to mean suppression of an actual fire.

As would tend to validate the need to establish electrical enclosures credited with VEWFDS as unique ignition sources, this treatment is expected to result in a very low count, perhaps zero, as there have been no known fires in such cabinets. But, a low count for this unique ignition source would not be unique or require the creation of any special techniques not previously used. Table 4-2 of NUREG-2169 lists multiple *sparse* Bins with low counts spanning 40 years, including:

BIN	COUNT
1 (Batteries)	1
5 (Cable fires due to C/W in the Control/Aux/Reactor Building)	1
16a (HEAF for low-voltage cabinets)	0.5
31 (Cable fires due to C/W in the Turbine Building)	1.5

Parameter estimation techniques such as described in NUREG/CR-6823 would be used to obtain a non-zero incipient event frequency even if the incipient event count turns out to be zero.

Due to the small number of electrical enclosures credited with VEWFDS, the incipient event frequency would be established on an ignition source basis rather than on a plant basis, as was done for NUREG-2169. For example, each section of a 10-count multi-bank at one plant would have the same incipient event frequency as each section of a 3-count multi-bank at a different plant. This would facilitate application and permit more meaningful comparisons among different plants in Phase II.

To obtain some insight into the overall impact of the prevention strategy, the sensitivity of the incipient event frequency to not counting the incipient events that are terminated prior to an actual fire should be evaluated. This should include consideration for both the VEWFDS status at the termination of a particular event and any similarity between the affected component and the initiating components previously identified in the ICES database. In particular, the incipient event frequency would be re-evaluated after adding, to the previously established incipient event count, the following fractional counts as appropriate for each incipient event terminated prior to an actual fire:

	VEWFDS Status	
Similar Component	ALARM	ALERT
YES	0.1	0.01
NO	0.01	0.0

This is based on ALERT at 0.2% obscuration/foot and ALARM at 1.0% obscuration/foot from NFPA 76.

Incipient Stage Duration

In the proposed event tree, the incipient stage duration was used to establish the time available in the associated Human Reliability Analysis (HRA). As advocated in NUREG-2180, the incipient stage duration will be based on information obtained from formal expert elicitation, employing experts knowledgeable of the design and failure characteristics of the equipment being protected and similar components. Section 8.2 of NUREG-2180 discusses additional considerations for characterizing an ignition source with

respect to the incipient stage duration. In addition to power or voltage, those considerations include the type of components and applicable failure mode or mechanism.

Establishing this incipient stage duration is envisioned as comprising two major efforts.

The first effort is to obtain information about the incipient stage duration for a variety of components typically found inside electrical enclosures credited with VEWFDS. The method for conducting the expert elicitation has not been established, but some general requirements are known. As a minimum, the collection of components should include those identified in ICES Fire Event Reports. For representative components under the conditions found in the applicable electrical enclosures, the duration of the incipient stage would be expressed as an expected (average) value, a maximum (95%) value, and a minimum (5%) value. This would provide some measure of the uncertainty in the results. Once identified, the experts may specify other types of information that they need to render an opinon.

The second effort is to apply the information to a particular ignition source. Based on an inventory of the components inside the electrical enclosure, the results of the expert elicitation would be combined to form a composite incipient stage duration for that particular electrical enclosure. The sensitivity of the relative contributions of the various components would be evaluated.

Time-table

This effort is envisioned in two Phases. In Phase I, the pilot plant will collect the operating experience, determine an incipient event frequency, and evaluate the risk. In parallel, EPRI will conduct the expert elicitation for incipient stage duration, support the creation of the incipient event reporting database, and report the results. In Phase II, other plants will contribute operating experience to the database and evaluate risk. At the end of Phase II, EPRI will publish an updated report.

INPO ICES database review	January 2018
Incipient Event Frequency Pilot	First Quarter 2018
Incipient Stage Duration Expert Elicitation	Second Quarter 2018
Phase I Report	Third Quarter 2018
Phase II	Fourth Quarter 2018
Phase II Report	First Quarter 2019

References

1) NUREG/CR-6850, EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Volume 2: Detailed Methodology, September 2005.

2) NUREG-2180, Determining the Effectiveness, Limitations, and Operator Response for Very Early Warning Fire Detection Systems in Nuclear Facilities, (DELORES-VEWFIRE), December 2016.

3) NUREG/CR-6823, Handbook of Parameter Estimation for Probabilistic Risk Assessment, September 2003.

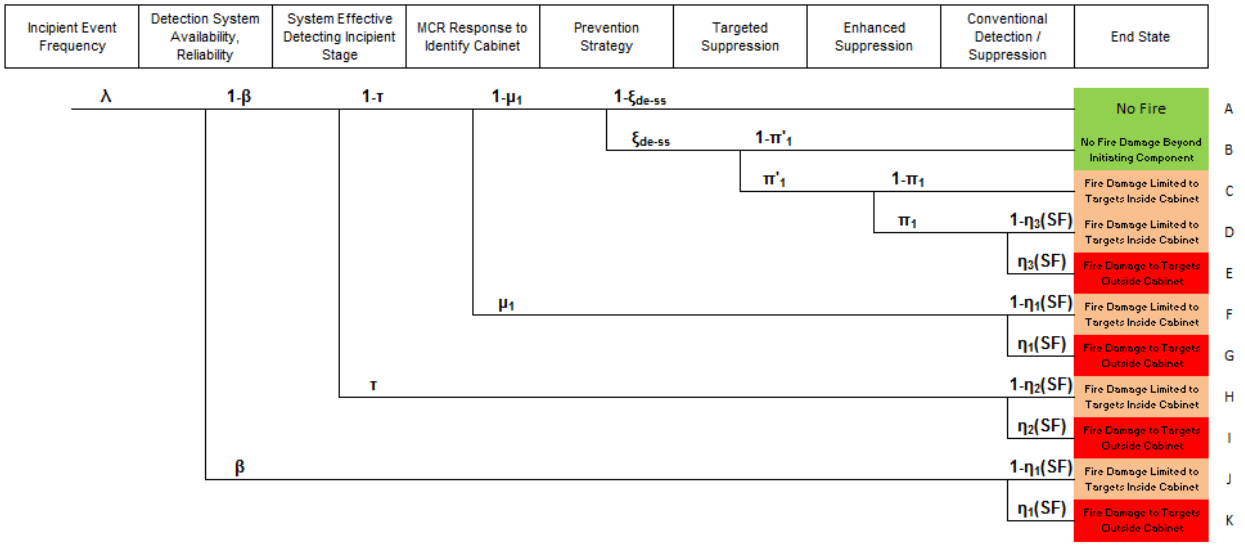

Figure 1: Proposed Event Tree for Quantifying the Risk Benefit of VEWFDS

To improve realism, the proposed event tree provides both an end state (A) where successful implementation of a Prevention Strategy results in "no fire" and an end state (B) where successful implementation of Targeted Suppression limits damage to only the initiating component. Other end states represent damage either to targets inside the cabinet or to targets both inside and outside the cabinet. To permit treatment of events prior to the occurrence of an actual fire, the severity factor (SF) for fire damage to targets outside the cabinet was moved to the conventional detection/suppression branch. The existence of significant conservatism is acknowledged in the retention of end states where the damage set jumps from a single component to the entire contents of a cabinet.

Incipient Event Frequency (λ): As an initiating event, the Incipient Event Frequency represents the likelihood for a challenging or potentially challenging fire in an electrical enclosure credited with in-cabinet VEWFDS. Part of the industry initiative would establish this frequency, by treating an electrical enclosure credited with in-cabinet VEWFDS as a unique ignition source, as described in Section 6.5.1 of NUREG/CR-6850. While an application-specific frequency might be more desirable, Operating Experience suggests there would likely be insufficient data to provide more than a generic estimate.

Detection System Availability and Reliability (β): This event represents the combination of generic ASD VEWFDS unreliability and unavailability from NUREG-2180 Tables 7-2 and 7-4, respectively. If sufficient data are available, individual licensees may use plant-specific (or fleet-specific) estimates instead of the generic estimates, as described in Sections 7.2.1 and 7.2.2 of NUREG-2180.

System Effective Detecting Incipient Stage (τ): This event represents the ASD VEWFD system-specific in-effectiveness estimates from NUREG-2180 Table 7-5, unless a licensee can establish an acceptable technical basis for using some other value, as described in Section 7.2.3.1 of NUREG-2180.

MCR Response to Identify Cabinet (μ): This event represents the efforts of the MCR operator beginning with the recognition of the VEWFDS ALERT and ending with the dispatch of personnel to respond to the incipient event. The HRA quantification for this event is described in Section 10.6 of NUREG-2180, which provides a basis for using CBDTM to establish an HEP of 1E-3 (without recovery). That basis is expected to remain valid for any anticipated incipient stage duration that would be developed by the industry initiative. To the extent that the VEWFDS ALARM precedes an actual fire, the VEWFDS ALARM represents an opportunity for self-recovery of the MCR response.

Prevention Strategy ($\xi_{de\text{-}ss}$): This event represents the efforts of personnel to implement the prevention strategy, beginning with the dispatch of personnel by the MCR operator and ending with either the occurrence of actual fire or the prior de-energization of the affected equipment. The scope of these efforts and the particular personnel required would be described in procedures reflecting the application-specific prevention strategy. For example, the procedures might require a technician to identify and de-energize a particular component in a multi-bank group of cabinets or, alternately, a field operator to de-energize an entire addressable cabinet outside the MCR. The HRA quantification for this event is described in Section 10.6 of NUREG-2180, with the clarification that the time available would be based on the incipient stage duration which would be established as part of the industry initiative.

Targeted Suppression (π'_1): This event represents the efforts of the field operator to limit fire damage to the initiating component, beginning with the dispatch by the MCR operator, continuing for the duration of the prevention strategy, and ending with either the spread of fire to some other component or the prior suppression of the fire. After arriving at the affected cabinet, the field operator is expected to remain vigilant at the affected cabinet with a "clean" (i.e., use does not fail other equipment in the cabinet) suppressant readily available as long as the threat of fire exists. The HRA quantification for this event is comparable to the in-cabinet fire suppression described in Section 10.6 of NUREG-2180, with the clarification that the time available would be based the incipient stage duration which would be established as part of the industry initiative. For this event, the time required for the field operator to arrive at the affected cabinet must account for the time for the technician to identify the affected cabinet in a multi-bank application.

Enhanced Suppression (π_1): This event represents the efforts of the field operator, having arrived in the area of the cabinet responsible for the VEWFDS ALERT, to limit the fire damage to the contents of a single cabinet. Unlike Targeted Suppression, this event does not require the identification of the affected cabinet, even for a multi-bank application. This event is consistent with the description in Section 11.1 of NUREG-2180, which provided a basis for using the MCR non-suppression probability curve (λ=0.324). Since damage to the entire cabinet is assumed even with the success of this event, there is no requirement to use a "clean" suppressant.

Conventional Detection/Suppression (η_1): As described in Section 11.2 of NUREG-2180, this event represents the failure probability of redundant detection and/or automatic suppression systems, that are available in the area, given that the VEWFD system has failed or the MCR has failed to respond.

Conventional Detection/Suppression (η_2): As described in Section 11.2 of NUREG-2180, this event represents the failure probability of redundant detection and/or automatic suppression systems given that the VEWFD system was able to provide prompt detection function event if unable to provide enhanced detection.

Conventional Detection/Suppression (η_3): This event differs from the description in Section 11.2 of NUREG-2180, in that redundant detection would be credited even where independent automatic fire suppression fails or is unavailable. Since this event follows successful MCR response to an VEWFDS ALERT, personnel would have already been dispatched in advance of an actual fire and would be more immediately available to validate the occurrence of a fire that would cause a conventional alarm. Under this situation, the expectation is that the fire brigade would arrive to find the field operator already engaged in fire suppression. For these reasons, use of the MCR curve (λ=0.324) is justified.

Date/Time ICES#	Component Initiating Fire	Other Information
1990-03-23 12:00 AM #303662	Control board/panel - Unspecified - INPO951594	wires to light switch
1991-10-20 12:00 AM #303685	Transformers, shunt reactors - Unspecified - INPO951604	300-699 VAC
1992-02-01 12:00 AM #303687	Waste Bin - Unspecified - INPO949924	Temporary heat trace
1992-03-03 12:00 AM #303688	Batteries, battery chargers - Unspecified - INPO951606	Transformers in bottom of Inverter
1995-03-18 12:00 AM #303710	Electrical conductors, bus, cable, wire - Unspecified - INPO951622	Temporary electrical wiring or equipment
1990-01-03 12:00 AM #303729	Transformers, shunt reactors - Unspecified - INPO951448	100-199 VAC
1990-03-30 12:00 AM #303731	Transformers, shunt reactors - Unspecified - INPO951450	300-699 VAC Transformer
1994-08-29 12:00 AM #303831	Circuit breakers, contactors, motor controllers, manual switches - Unspecified - INPO951491	cable insulation breakdown
1994-07-27 12:00 AM #303896	Waste Bin - Unspecified - INPO950134	cable insulation due to failure of EDG roto test switch