FAQ Number	**17-0012**	**FAQ Revision**	**0e**
FAQ Title	**Incipient Detection for Fire Prevention and Suppression**		

Plant:	Harris	Date:	July 10, 2017
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Purpose of FAQ:

This FAQ supplements guidance in NUREG-2180 to provide more realistic 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.

Is this Interpretation of guidance? Yes / No

Proposed new guidance not in NEI 04-02? Yes / No

Details:

NRC document needing interpretation (include document number and title, section, paragraph, and line numbers as applicable):

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 (Section 10).

Circumstances requiring interpretation of guidance or new guidance:

In modifying the non-suppression event trees shown in Figure 6-4 and Figure 6-5 to incorporate the prevention strategy shown in Figure 6-6, the MCR response for an incipient ALERT and an incipient ALARM are combined, although these are different

cues to activate different responders. Consequently, the prevention strategy, which is actually a suppression strategy, likewise combines these different responders.

Detail contentious points if licensee and NRC have not reached consensus on the facts and circumstances:

Properly crediting a fire prevention strategy is difficult because the more aggressively it is pursued the less evidence there is of success. For example, 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. So, while we don't want to over-credit something that is really unknowable, we also don't want to accept assumptions or techniques that discourage a fire prevention strategy.

Potentially relevant existing FAQ numbers:

FAQ 08-0046, "Incipient Fire Detection Systems" (retired 7-1-2016, ML16167A444)

FAQ 08-0050, "Manual Non-Suppression Probability"

Response Section:

Proposed resolution of FAQ and the basis for the proposal:

For fire prevention and suppression crediting incipient detection, a common event tree (Figure 1) for both in-cabinet and area-wide applications is proposed based on the event trees in Figures 6-4, 6-5, and 6-6 of NUREG-2180. The proposed event tree separates the incipient ALERT and incipient ALARM, including the associated responses, and distinguishes the prevention event from the targeted suppression event. Targeted suppression is limited to the initiating component and does not assume, as was done in NUREG-2180, that "…suppression activities regardless of form damage the ability of components within a cabinet to perform their intended design function." For the prevention event, parameter estimates are based on available operating experience.

In describing the proposed event tree, repetition of applicable information already provided in NUREG-2180 is minimized.

Fire Initiating Event (λ): The initiating event is a potentially challenging or greater fire involving a specific component or compartment of the plant. However, because the proposed event tree includes end states other than "Cabinet Damage" or "Fire Damage Outside Cabinet," the Severity Factor should be combined later in the tree with the event associated with damage outside the cabinet. Although focused on Bin 15 ignition sources, NUREG-2180 noted that operating experience has demonstrated that use of VEWFD system is applicable to other types of components.

Detection System Unavailability and Unreliability (β): As described in Section 7.2 of NUREG-2180, this event represents the combined unavailability and unreliability for the VEWFD system and, for the air return application, the ventilation system.

Fraction of Fires Without an Incipient Phase Detectable by System (α): As described in Section 7.1 of NUREG-2180, this event represents the fraction of fires that have an incipient stage less than a nominal minimum threshold. NUREG-2180 proposed a nominal minimum threshold of 30 minutes. This 30-minute threshold was based on an assumed maximum 15-minute response time for plant personnel to arrive at the scene and the test data that showed detector response typically occurring half-way through the test duration.

After personnel arrive at the scene, some addition time will be required to implement an effective prevention strategy. Therefore, an alternate minimum threshold of at least 1 hour is proposed, assuming 30 minutes for detector response and 30 minutes for operator response. This minimum threshold does not ensure that the prevention strategy will be effective, but the prevention strategy is expected to be more effective when the incipient stage is greater than the minimum threshold.

A 1-hour minimum threshold resulted in the elimination of one event (EPRI FEDB #161) from consideration as an incipient event for the power cabinets, because that event had an assumed incipient duration of 30 minutes. Extending the nominal minimum threshold to at least 1 hour did not have a greater impact because demand failures tend to be prompt whereas degradation tends to occur more slowly over time. As noted in Section 7.1 of NUREG-2180, the identification of events with an incipient phase needs to consider the failure mechanism to make an informed decision. As a result, Table 7-1 of NUREG-2180 is changed to:

Category	Incipient Stage Detectable by VEWFD System			Total Number of Events	Fraction (alpha) Mean [lower/upper]
	Yes	No	Undetermined		
Power Cabinets	15.5	17	22.5	55	0.50 [0.40 / 0.60]
Low Voltage Control Cabinets	6	2	5	13	0.28 [0.08 / 0.54]

System Incipient Detection Ineffectiveness (τ): As described in Section 7.2.3 of NUREG-2180, this parameter represents the ineffectiveness of the incipient system to perform given the anticipated operational scenarios.

Unsuccessful MCR Operator Response to Incipient ALERT (μ_1): The MCR Operator must dispatch both the I&C Technician and the Field Operator to the correct location upon receipt of an incipient ALERT for the VEWFD system. Upon arrival at the correct location, the Field Operator is expected to remain there until either the incipient ALERT clears or, if the event progresses to an actual fire, the fire is suppressed. Unless the incipient ALERT clears, the I&C Technician is expected to pursue the identification of the degraded component and the associated fire prevention strategy. After identifying the degraded component, the I&C Technician may be required to change location while the incipient ALERT is active to obtain more information in support of the fire prevention strategy. Where NUREG-2180 included the dispatch of the Fire Brigade upon receipt of an incipient ALARM, that event is defined separately for the proposed event tree as "μ_2". This separation does not improve the associated HEP for "μ_1" which is at the floor of 1E-4, for all types of VEWFD systems.

Unsuccessful Fire Prevention at Incipient ALERT (δ_1): This event represents fire prevention at the incipient ALERT phase and is a simpler alternative to the "$\xi_{de\text{-}ss}$" event in Section 10.6.4 of NUREG-2180. This parameter is estimated from operating experience using a Jeffery's non-informed approach assuming a binomial data set (i.e., the event progresses from the incipient phase to fire, or it does not). However, the most relevant operating experience is not contained in the EPRI FEDB because there has been no fire event where incipient detection was credited.

Instead this parameter was estimated from four events at Harris where in-cabinet incipient detection was credited. As documented in the CAP and summarized below, these events were terminated at the ALERT stage prior to causing a fire:

Date	CAP	Description	Resolution
06/17/2013	612158	Overheated resistors scorching terminal board	De-energize device and eliminate resistors contact with plastic raceway
11/24/2013	648007	Overheated resistors	De-energize device and move wires away from resistors
08/01/2015	1938438	Resistor in control switch	De-energize and replace switch
08/11/2016	2055098	Resistor in control switch>300°F	De-energize and replace switch

The resulting posterior beta distribution has parameters "α" and "β" as:

α = (number of events that progress to fire) + 0.5	= 0 + 0.5	= 0.5
β = (number of events) - (number of events that progress to fire) + 0.5	= 4 - 0 + 0.5	= 4.5
$\delta_1 = \alpha / (\alpha + \beta)$	= 0.5/(0.5 + 4.5)	= 0.1

Success with this fire prevention strategy was obtained with relatively simple procedures performed by trained and experienced personnel, who had access to typical plant documentation.

While the operating experience includes no event where area-wide incipient detection was actually credited, the "2013 event" and the "2014 event" in Appendix D of NUREG-2180 provide useful insights on the performance of in-cabinet incipient detection in a "pseudo area-wide" capacity. In each event, the in-cabinet incipient detectors provided 1 to 2 hours advance warning of an event in a power panel located across a large room (see Figure 2). For the 2013 event, the I&C Technician was dispatched 8 minutes after the event started and was able to identify the cause and report to the MCR 13 minutes later. The cause of the 2014 event was similar to the 2013 event and was likewise identified relatively early in the event. Properly designed, installed, and maintained area-wide VEWFD systems would be expected to perform at least as well as these "pseudo area-wide" incipient detectors.

Before this operating experience can be extended to a properly designed, installed, and maintained area-wide VEWFDS, some qualification on the expected success of the prevention strategy is necessary. Although actions were underway to isolate the degraded equipment at the time each event progressed to fire, the prevention strategy was unsuccessful in part because there was no plan to use the in-cabinet incipient detection beyond their intended function. Had there been a pre-planned response, the likelihood of the success of the prevention strategy would have been much improved. Therefore, a weighting factor (0.5) is used to represent whether the actions would have been successful had an appropriate plan existed at that time. The HEP is estimated to be:

α = (number of events that progress to fire) + 0.5	= 2*0.5 + 0.5	= 1.5
β = (number of events) - (number of events that progress to fire) + 0.5	= 2 - 2*0.5 + 0.5	= 1.5
$\delta_1 = \alpha / (\alpha + \beta)$	= 1.5/(1.5 + 0.5)	= 0.75

To avoid unnecessary perturbations to the plant, the response should be based on the receipt of the incipient ALARM which followed 10 minutes and 2 minutes after the incipient ALERT, for the 2013 event and the 2014 event, respectively. Alternately, if more credit is desired, a plant-specific, detailed HRA may be developed for the "$\xi_{de\text{-}ss}$" event as described in Section 10.6.4 of NUREG-2180.

Unsuccessful MCR Operator Response to Incipient ALARM (μ_2): The MCR Operator must dispatch the I&C Technician (if not previously dispatched for the incipient ALERT) and the Fire Brigade to the correct location upon receipt of an incipient ALARM for the VEWFD system. Upon arrival at the correct location, the Fire Brigade is expected to lead any fire fighting activities, taking over for the Field Operator (if previously dispatched for the incipient ALERT) and to remain there until either the incipient ALARM clears or, if the event progresses to an actual fire, the fire is suppressed. If the incipient ALARM clears but the incipient ALERT remains active, the Field Operator is expected to resume the previous duties. This event was separated from "μ_1" because the cue is different, the timing is different, and some responders are different.

To obtain the lambda for the time available after the incipient ALARM, the operating experience from the only two events actually having an incipient ALARM (i.e., the "2013 event" and the "2014 event") was combined with the information in Table D-2 of NUREG-2180. From these two known events, a delta time (between incipient ALERT and incipient ALARM) was apportioned for the other events based on the estimated time available from the incipient ALERT listed in Table D-2. For the 4.75 hours surrogate of the 2015 event (which actually exhibited an incipient phase of 90 hours without an incipient ALARM), a surrogate delta time of 0.75 hours was used. The results are listed in Table 1.

The lambda for incipient ALARM was less than the lambda for incipient ALERT, indicating more time available than previously credited. But for incipient events of relatively short duration, there could be some overlap in the timing with "μ_1". To account for this potential dependency, the recovery credit in "μ_1" was removed to obtain an associated HEP for "μ_2" of 1E-3.

This event is also applicable to fires that do not provide sufficient time for an effective response to an incipient ALERT but where it would be appropriate to credit prompt detection for a successful MCR Operator response to an incipient ALARM. In such cases, the associated HEP for "μ_2" remains 1E-3.

Unsuccessful Fire Prevention at Incipient ALARM (δ_2): This event represents fire prevention at the incipient ALARM phase and, like the previously developed "δ_1" event, is a simpler alternative to the "$\xi_{de\text{-}ss}$" event in Section 10.6.4 of NUREG-2180. This event only applies for sequences where the MCR Operator failed to respond to the incipient ALERT because the I&C Technician would already be engaged in the fire prevention strategy otherwise. Based on the relatively small delta times between incipient ALERT and incipient ALARM as listed in Table 1 when compared to the duration of the incipient phase, the HEP for "δ_2" is the same as previously determined for "δ_1".

Alternately, if more credit is desired, a plant-specific, detailed HRA may be developed for the "$\xi_{de\text{-}ss}$" event as described in Section 10.6.4 of NUREG-2180.

Targeted Suppression (ξ): This event represents fire suppression at the individual component level based on a statistical model of non-suppression probability for a zero-length fire in a control cabinet. This suppression approach is similar to a special application of the Appendix L treatment of fires on the Main Control Board. To credit targeted suppression, the suppression agent must not impair the ability of other components within the cabinet to perform their intended design function.

Two variations of this parameter were considered: the failure of the Field Operator following success of the MCR Operator Response to Incipient ALERT "μ_1", and the failure of the Fire Brigade following success of the MCR Operator Response to Incipient ALARM "μ_2". With respect to suppressing a small fire at the component level, the Field Operator and the Fire Brigade were considered equally capable. The statistical model was developed for Fire Brigade response times and would be conservative for the Field Operator. It is important to note that both the incipient ALERT and the incipient ALARM would be received in advance of an actual fire, but no targeted suppression would be attempted before the observation of actual fire.

The development of the statistical model did not require the identification of the degraded component, and its use would be conservative with even partial success of the I&C Technician. From Table 10-4 of NUREG-2180, the time required for the I&C Technician to identify the degraded component is estimated to be between 8 and 30 minutes after successful MCR response. Since the fraction of events that would progress from incipient ALERT to fire in less than 30 minutes was already addressed by "α", the pre-fire observation of the specific component would be very likely. In addition, the I&C Technician will have identified the cabinet containing the degraded component much sooner, providing an opportunity to limit the scope of pre-fire observations.

Figure 3 provides the HEP based on a statistical model of non-suppression probability for a zero-length fire in a control cabinet.

For a power cabinet, targeted suppression is not considered feasible (i.e., **ξ** = 1.0).

Enhanced Suppression (π): This event represents fire suppression prior to damage outside the cabinet, where targeted suppression at the component level has failed. Unlike targeted suppression, enhanced suppression does not require the suppression agent to not impair the ability of components within the cabinet to perform their intended design function.

Like targeted suppression, two variations of this parameter were considered: the failure of the Field Operator following success of the MCR Operator Response to Incipient ALERT "μ_1", and the failure of the Fire Brigade following success of the MCR Operator Response to Incipient ALARM "μ_2". Consequently, both variations include arrival at the correct location prior to an actual fire, but neither variation requires the successful identification of the degraded component by the I&C Technician.

With respect to suppressing a growing fire prior to damaging targets outside the cabinet, the Field Operator and the Fire Brigade were not considered equivalent. While the Field Operator is a trained responder, the Fire Brigade arrives with a team of additional resources, equipment, organizational support, and capabilities to address any postulated fire. Section 11.1 of NUREG-2180 describes the appropriate use of the MCR curve (λ=0.324) for performance of the Field Operator for in-cabinet events "π_1" and a newly developed curve (λ=0.324) for area-wide events "π_2". However, the performance of the Fire Brigade (π') should use the MCR curve for both an in-cabinet and area-wide VEWFD system. Use of the MCR curve rather than the newly developed curve is considered a reasonable representation for Fire Brigade performance for an area-wide VEWFD system given that more trained responders, with more equipment, will be near the bank of cabinets where the VEWFD system ALARM was initiated, actively searching for the source location of the ALARM.

Conventional Detection / Suppression (η): This event represents the conventional fire suppression probability, as described in Section 11.2 of NUREG-2180, with two recommended changes.

First, more realistic treatment of the incipient stage is recommended when crediting incipient detection for prompt detection in "η_2", where the issue is whether the fire can be suppressed before damaging targets outside the cabinet. Most fires that have a growth profile are also expected to exhibit a detectable incipient stage, even when the duration of that incipient stage is less than the 1 hour necessary for an effective prevention response. Simply assuming the time to detection at ignition would often be overly conservative and is inconsistent with a general observation from NUREG-2180 that incipient detector response typically occurred half-way through the tests that ended in cable damage conditions.

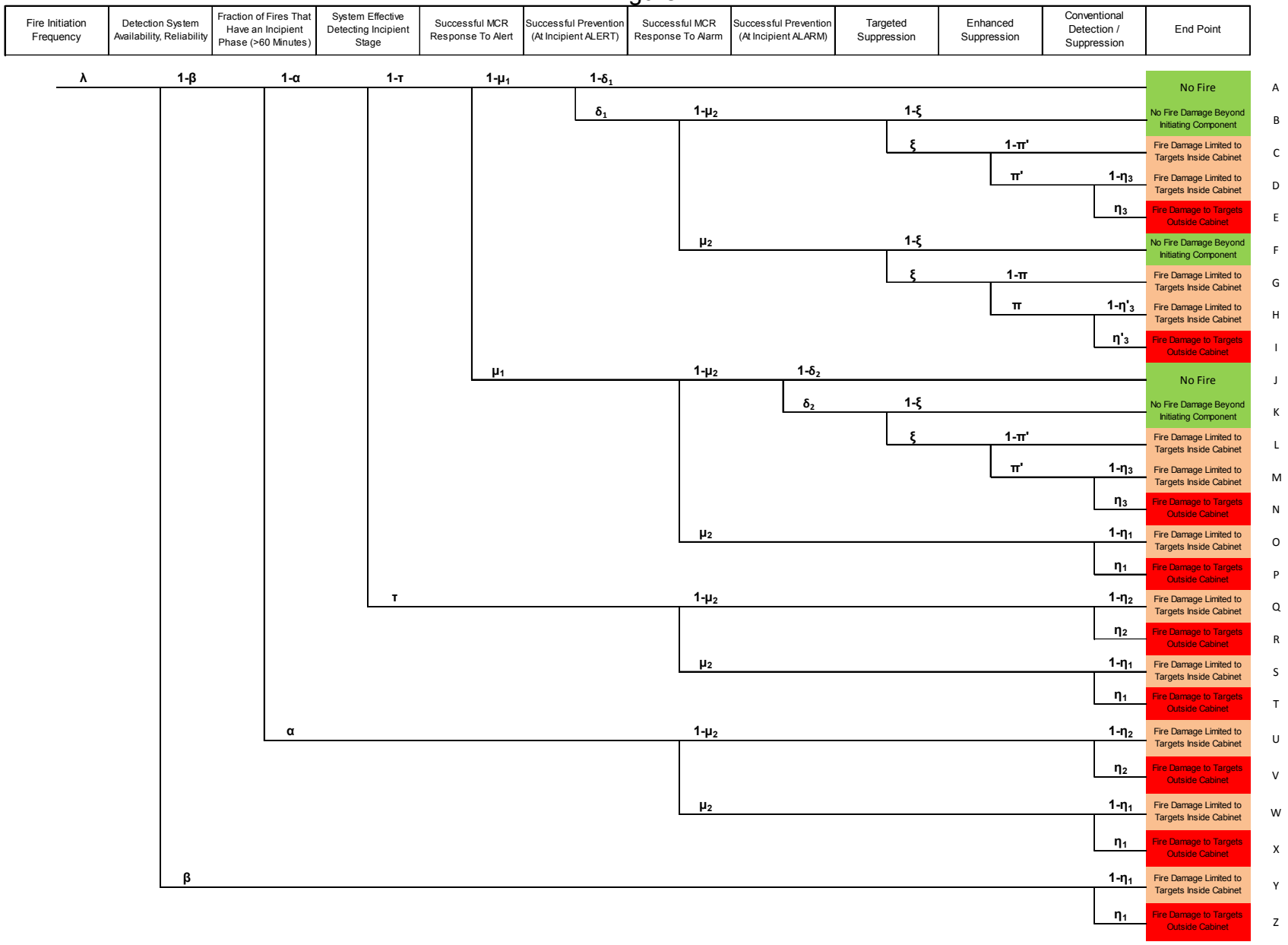
For fires described by the "α" branch in Figure 1, the general observation from NUREG-2180 suggests that the incipient ALARM can be expected to occur between 0 and 30 minutes prior to reaching cable damage conditions. However, incipient detection is selectively applied and all of the fires described by the "α" branch in Figure 1 would not be considered to be good candidates. For systems installed consistent with the guidance in Section P.1.3 of NUREG/CR-6850, a good candidate would be expected to

provide 5 minutes of additional warning between the incipient ALARM and ignition. That time between incipient ALARM and ignition could be credited as additional time to target damage or equivalently as additional time available for suppression. The operating experience from the 87 (and counting) detector-years listed in Table 7-3 of NUREG-2180 for U.S. NPPs supports the use of 5 minutes as reasonably realistic yet conservative. Individual plants could use a different number with additional justification.

Second, inclusion of the Fire Brigade in conventional suppression for "η_3" is recommended when enhanced suppression "π" is provided by the Field Operator. No additional credit is provided for manual suppression when the Fire Brigade is credited for enhanced suppression. The change became necessary when the responses of the Field Operator and the Fire Brigade were separated. In Figure 1, the prime mark (') indicates when the Fire Brigade is credited either for enhanced suppression or conventional suppression.

***If appropriate, provide proposed rewording of guidance for inclusion in the next Revision*:**

Figure 1


Fire Initiation Frequency
Detection System Availability, Reliability
Fraction of Fires That Have an Incipient Phase (>60 Minutes)
System Effective Detecting Incipient Stage
Successful MCR Response To Alert
Successful Prevention (At Incipient ALERT)
Successful MCR Response To Alarm
Successful Prevention (At Incipient ALARM)
Targeted Suppression
Enhanced Suppression
Conventional Detection / Suppression
End Point
λ
1-β
1-α
1-τ
1-μ1
1-δ1
δ1
1-μ2
1-ξ
ξ
1-π'
π'
1-η3
η3
μ2
1-ξ
ξ
1-π
π
1-η'3
η'3
μ1
1-μ2
1-δ2
δ2
1-ξ
ξ
1-π'
π'
1-η3
η3
μ2
1-η1
η1
τ
1-μ2
1-η2
η2
μ2
1-η1
η1
α
1-μ2
1-η2
η2
μ2
1-η1
η1
β
1-η1
η1
No Fire
No Fire Damage Beyond Initiating Component
Fire Damage Limited to Targets Inside Cabinet
Fire Damage to Targets Outside Cabinet
A
B
C
D
E
F
G
H
I
J
K
L
M
N
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P
Q
R
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Y
Z

Figure 2

August 2013 Fire on 6.9kV/480V Transformer for Aux Bus 1E2 in Switchgear Room B

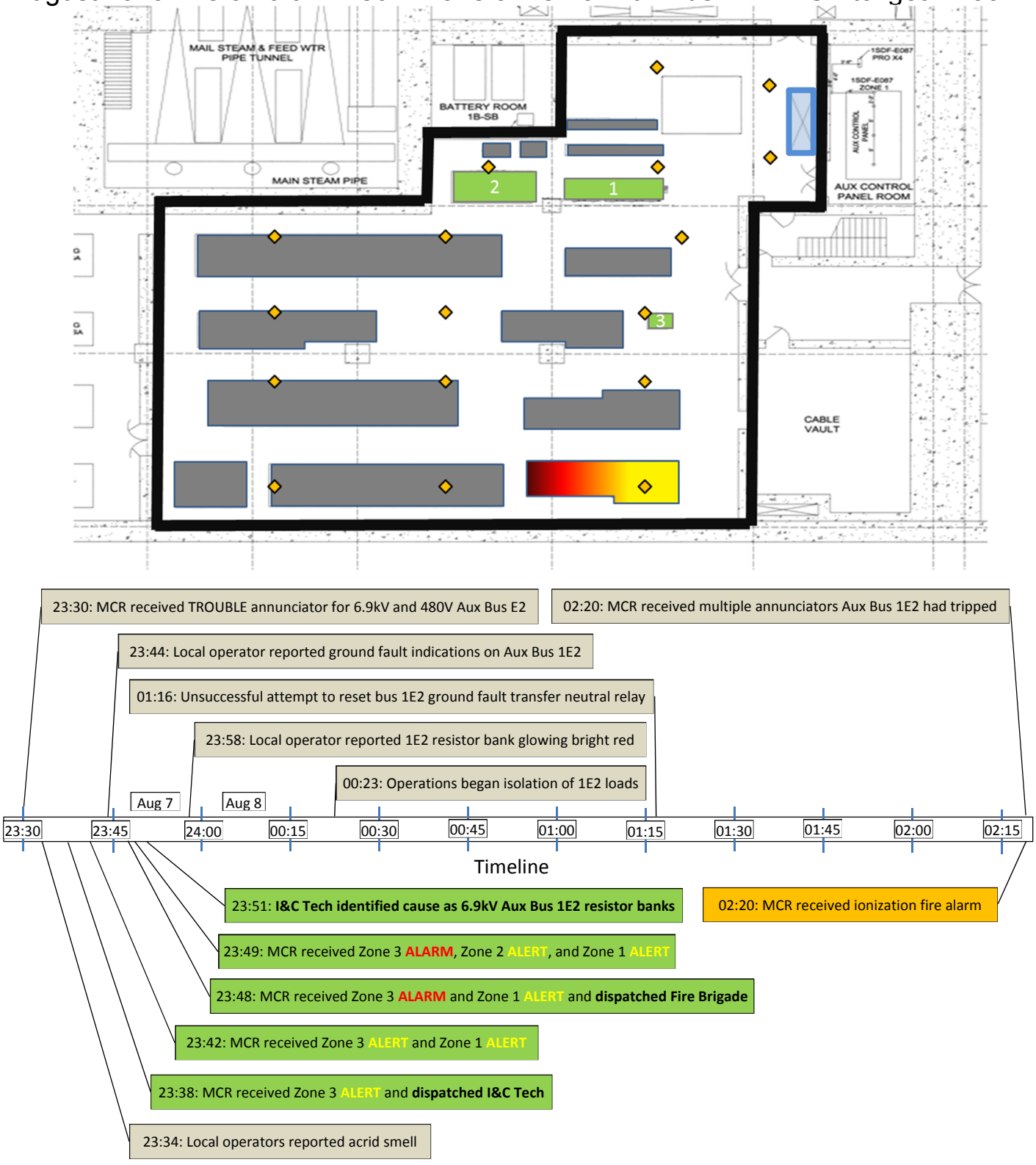
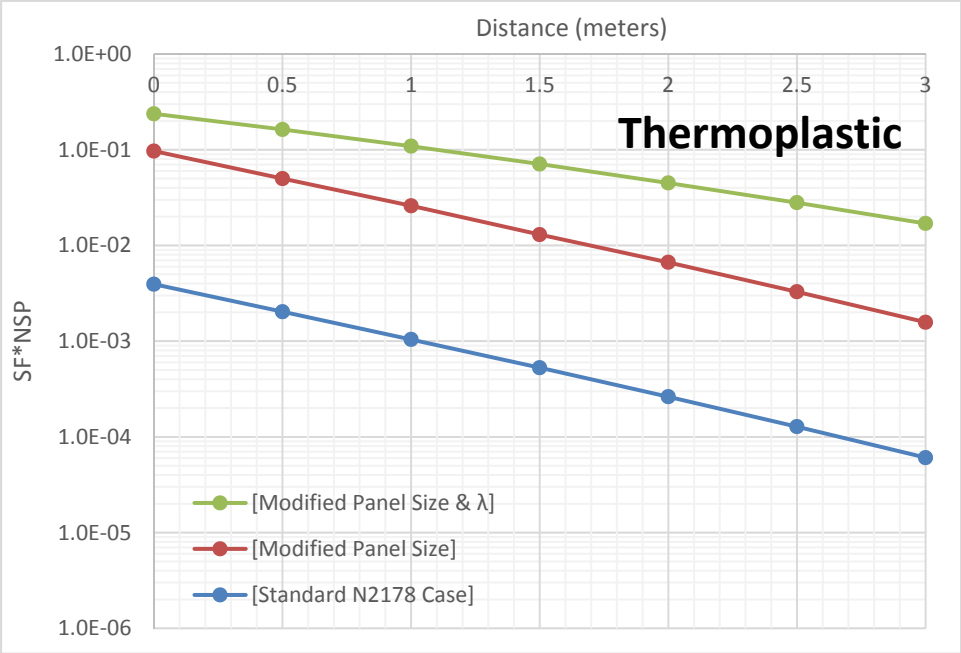
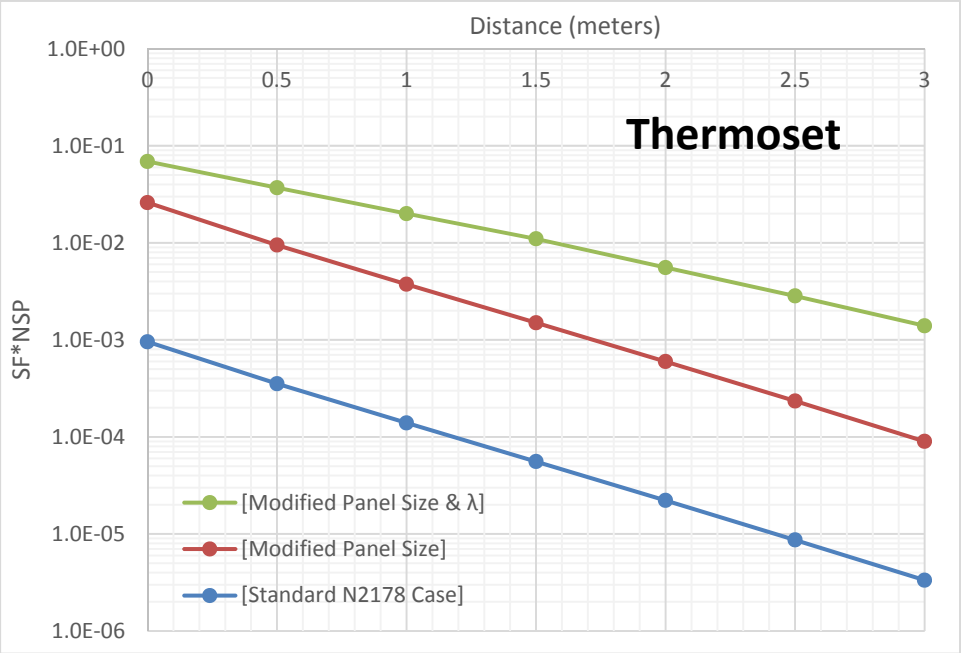


Figure 3
Statistical Zero-Length Non-Suppression Probability





CONFIGURATION						THERMOPLASTIC				THERMOSET			
[Standard N2178 Case]	d (m)	W (ft)	H (ft)	t.det	λ	Tdam (C)	α	β	SF*NSP	Tdam (C)	α	β	SF*NSP
(2178 Class 4a Lg, closed, W=60ft) - 0 m distance	0	60	10	0	0.324	205	0.52	145	3.942E-03	330	0.23	223	9.557E-04
[Modified Panel Size]	d (m)	W (ft)	H (ft)	t.det	λ	Tdam (C)	α	β	SF*NSP	Tdam (C)	α	β	SF*NSP
(2178 Class 4a Lg, closed, W=3ft) - 0 m distance	0	3	7	0	0.324	205	0.52	145	9.700E-02	330	0.23	223	2.600E-02
[Modified Panel Size & λ]	d (m)	W (ft)	H (ft)	t.det	λ	Tdam (C)	α	β	SF*NSP	Tdam (C)	α	β	SF*NSP
(2178 Class 4a Lg, closed, W=3ft) - 0 m distance	0	3	7	0	0.098	205	0.52	145	2.380E-01	330	0.23	223	6.900E-02

Table 1
Lambda For Time Available After Incipient ALARM

Table D-2 Supplement	Incipient Phase (hrs)	Delta Time (hrs)	ASD CC		ASD LS-SS		ION		PHOTO	
			ALERT	ALARM	ALERT	ALARM	ALERT	ALARM	ALERT	ALARM
EPRI FEDB 161	0.5		0.26		0.13		0.17		0.04	
EPRI FEDB 50836	0.9		0.47		0.23		0.31		0.07	
SNZ z-machine	0.98		0.51		0.26		0.33		0.08	
2014 Event		0.03	1.12	1.09	0.56	0.54	0.73	0.71	0.17	0.16
2013 Event		0.17	2.75	2.58	1.38	1.30	1.80	1.69	0.42	0.39
EPRI FEDB 10647	7	0.58	3.64	3.06	1.82	1.53	2.38	2.00	0.56	0.47
2015 Event		0.75	4.75	4.00	2.38	2.00	3.11	2.62	0.73	0.61
Lambda (2180)			*0.518*		*1.036*		*0.793*		*3.382*	
Lambda			*0.326*	*0.373*	*0.651*	*0.745*	*0.499*	*0.570*	*2.128*	*2.432*

* shaded information copied from Table D-2 of NUREG-2180