FAQ Number	**13-0001**	**FAQ Revision**	**0a**
FAQ Title	**Clarifications on Treatment of VEWFDS to Support NFPA 805 Risk Analysis**		

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Purpose of FAQ:

The purpose of the FAQ is clarify the treatment of incipient fire detection systems in a Fire PRA Model used to support NFPA 805. Specifically the two areas addressed by this FAQ are:

- Continuously occupied locations (including within MCBs)
- Area-wide in a non-continuously occupied location

Guidance for the treatment of such a system with respect to hardware failure rates and its relationship with the NUREG/CR-6850 / EPRI TR-1011989, Appendix P treatment of fire suppression is not currently available.

Details:

NRC document needing interpretation (include document number and title, section, paragraph, and line numbers as applicable):
None

Circumstances requiring guidance interpretation or new guidance:
New guidance

Detail contentious points if licensee and NRC have not reached consensus on the facts and circumstances:
None

Potentially relevant existing FAQ numbers:
FAQ 08-0046 (NUREG/CR-6850, Supplement 1): Incipient Fire Detection Systems
FAQ 08-0050 (NUREG/CR-6850, Supplement 1): Manual Fire Non Suppression Probability

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Response Section:

Proposed resolution of FAQ and the basis for the proposal:

INTRODUCTION

The purpose of Fire PRA FAQ 13-0001 is to provide supplemental guidance for the treatment of aspirating smoke detectors (ASD) installed as very early warning fire detectors (VEWFDs) as defined by NFPA 76 (2009). The treatment of such a system in a fire PRA (FPRA) is described in NFPA 805 FAQ 08-0046 (NUREG/CR-6850, Supplement 1). However, based on discussions with the NRC, FAQ 08-0046 is only applicable for in-cabinet installations in locations that are not continuously occupied. The purpose of FAQ 13-0001 is to address the treatment of an ASD installed as a VEWFD for two additional applications.

- Continuously occupied locations (including within MCBs)
- Area-wide in a non-continuously occupied location

BACKGROUND

The current NRC interpretation of the guidance in FAQ 08-0046 is that it is only applicable to locations that are not continuously occupied. In addition, successful response to an ASD alarm condition can only be credited for preventing fire propagation unless details beyond that presented in the FAQ is developed. No guidance is currently available when an ASD system is installed in a continuously occupied location, in an area-wide application, or if such a system is relied upon as part of an integrated response to prevent the occurrence of a fire.

The basis for the limited application of FAQ 08-0046 is not explicitly documented but can be inferred from the details provided in the FAQ.

- Only for locations that are not continuously occupied: The existing FPRA treatment guidance includes manual fire suppression failure probabilities in NUREG/CR-6850, Appendix P and FAQ 08-0050 (Supplement 1). This existing guidance provides credit for improved manual suppression reliability for the Main Control Room (MCR) (i.e., a continuously occupied location). In addition, the recommended treatment for the Main Control Board (MCB) in the MCR in NUREG/CR-6850, Appendix L includes credit for manual suppression. As such, there is some potential dependency between reliability of fire suppression given an ASD system versus that without such a system. Using the ASD treatment as described in FAQ 08-0046 would effectively treat it as an independent parameter and would ignore this potential dependency.

- Can only be credited for preventing fire propagation: One of the event tree nodes in FAQ 08-0046 is identified using the parameter δ, “Technician Successful in Preventing Fire in Incipient Stage.” The simplified version of the event tree that was ultimately used in FAQ 08-0046 notes that this node is set to 1.0. If the simplified event tree is used and the typographical error corrected in the characterization of sequences 1 and 2, then all sequences from the event tree result in at least damage throughout the cabinet.

DISCUSSION

The current treatment of postulated fires in the MCB is described in NUREG/CR-6850, Appendix L. Although the guidance in this Appendix is applicable only to the MCB, it provides key insights as to the treatment of fire detection and suppression. A key insight from this guidance is that the conditional probability that a fire at any location within the MCB results in damage beyond the ignition source is less than 6E-3. This value is taken from Figure L-1 using d = 0 m. As described in Appendix L, this value would be multiplied by the MCB fire frequency to obtain the frequency of the specific event. The discussion in Appendix L and the development of the analysis used to generate the results shown in Figure L-1 shows that credit for manual suppression using the λ term of 0.33 from Appendix P is included.

In Section P.1.3, the following two items are noted:

> *If in-cabinet smoke detection devices are installed in the electrical cabinet postulated as the ignition source, the analyst should assume that the fire will be detected in its incipient stage. This incipient stage is assumed to have a duration of 5 minutes.*
>
> *Prompt detection should be only credited when … a high-sensitivity smoke detection system is installed. …*

The following treatments can therefore be considered to be within the existing methodology of NUREG/CR-6850.

- If an in-cabinet smoke detector is available in the MCB, then the Appendix L treatment can be modified to provide an additional 5 minutes for fire suppression.

- If an in-cabinet smoke detector is available in an electrical cabinet (panel), then successful suppression at 5 minutes would be equivalent to no damage beyond the incipient source within the cabinet.

- If a high-sensitivity smoke detector is installed in a non-continuously manned location, then the prompt suppression (welding) treatment should be used.

The treatment framework already described in NUREG/CR-6850 will be used to establish an 'anchor' point as part of the process of developing recommendations for the crediting of an ASD installed as a VEWFD as defined by NFPA 76 for applications beyond those addressed by FAQ 08-0046.

<u>In-Cabinet Smoke Detectors</u> – The credit available for the presence of in-cabinet smoke detectors is described in NUREG/CR-6850. Three cases are considered:

1. MCB panel in the MCR
2. Non-MCB panel in the Main Control Room
3. Electrical cabinet in a non-continuously occupied location

    1. MCB Panel in the MCR – The current guidance in NUREG/CR-6850 recommends that a FPRA treat the presence of an in-cabinet smoke detector in the MCB by considering the availability of an alarm before it would have otherwise been detected by the control room

operators. The guidance states that this advance warning would occur during an assumed 5 minute incipient period. This credit in the treatment can be directly calculated using the information in Appendix L.

From Appendix L :

$$[SF \bullet P_{ns}](d) = \frac{1}{H \bullet W} \int_0^H \int_0^W SF(d,w,h) \bullet P_{ns}(d,w,h) dwdh$$

$$P_{ns}(d,w,h) = e^{-\lambda \bullet t}$$

With a traditional non-aspirating (e.g., ionization) smoke detector installed inside the MCB, the suppression term $e^{-\lambda t}$ would become $e^{-\lambda(t+5)}$. The ratio of these two factors can then be applied to the original equation from Appendix L. The net result is that a constant factor is added as shown below.

$$[SF \bullet P_{ns}](d) = \frac{1}{H \bullet W} \int_0^H \int_0^W SF(d,w,h) \bullet P_{ns}(d,w,h) dwdh \bullet \frac{e^{-\lambda \bullet (t+5)}}{e^{-\lambda \bullet t}}$$

$$[SF \bullet P_{ns}](d) = e^{-\lambda \bullet 5} \bullet \frac{1}{H \bullet W} \int_0^H \int_0^W SF(d,w,h) \bullet P_{ns}(d,w,h) dwdh$$

$$\lambda = 0.33, \; and \; therefore, \; e^{-\lambda \bullet 5} = 0.19$$

This development shows that if a traditional non-aspirating smoke detector were to be installed in a MCB, application of the existing guidance in NUREG/CR-6850 would result in the factors taken from Appendix L, Figure L-1, being reduced by a factor of 0.19. Including hardware failure would result in this value being increased to 0.24 (0.19 + .05). If instead, an ASD installed as a VEWFD were to be used instead, the associated reduction factor should be lower than 0.24. The lower value would be based on the additional time associated with the advance warning that would be appropriate given the presence of an ASD system. Although FAQ 08-0046 assumes that, an hour of warning would be available, that timing is based on the onset of open flaming. It is evident that prior to open flaming, enough smoke would be generated that it would be recognized by the MCR staff. In order to eliminate concerns related to dependencies between the detection mechanisms while still providing for a reasonable credit for the ASD system, a

value less than 60 minutes should be used. As an example, the advance warning time could be increased from 5 minutes to 10 minutes (ASD system provides an additional 5 minutes of advance warning). In addition, the screening hardware failure probability of 0.01 from FAQ 08-0046 should also be included.

$$e^{-\lambda(10)} + 0.01 = e^{-0.33(10)} + 0.01 \sim 0.05$$

It is recognized that the result of this treatment is sensitive to the time duration assumed. The results of a sensitivity study as the value of this additional delay varies.

Continuously Occupied Location	
ASD Detection Credit (min.) [1]	Appendix L Adjustment Factor
0	0.20
5	0.05
10	0.02
15	0.01
20	0.01
25	0.01
30	0.01

Note 1: The time duration refers to the additional time warning provided by the ASD system as compared to a traditional non-aspirating smoke detector

In order to provide interim guidance that reasonably credits the advantages and benefits of an ASD system while maintaining a degree of conservatism pending further research, it is recommended that a factor of 0.02 be used. This is based on the ASD system providing an additional 10 minutes of advance warning over that which would be provided by a non-aspirating smoke detector installed in the MCB. As noted above, this value should be applied together with the parameters from Figure L-1 of NUREG/CR-6850.

The extent of internal fire damage within the MCB should be treated using the existing guidance in Appendix L of NUREG/CR-6850.

2. Non-MCB Panel in the Main Control Room – The current guidance in NUREG/CR-6850 recommends that a FPRA treat the presence of an in-cabinet smoke detector by considering the availability of an alarm before it would have otherwise been detected by other means. The guidance states that this advance warning would occur during an assumed 5 minute incipient period. As discussed in the previous section, if an ASD

installed as VEWFD were to be used instead, additional advance warning would be available. The previous treatment provides a sensitivity study for the fire suppression failure as a function of the ability to detect the fire in its incipient phase. The recommended treatment for the MCB assumes that an additional 10 minutes of time would be available. For the non-MCB panels, additional time could be available.

The treatment for the MCB limited the additional advance warning to 10 minutes. This limited credit is intended to address the potential overlap of detection by the ASD system and detection by the MCR staff by smell. For the non-MCB panels, additional time would be available if the panel is not located in the same general proximity to the MCR staff as the MCB. A review of the sensitivity study in the prior section shows that if an additional 5 minutes of available time (15 minutes of additional time) the resultant non-suppression factor would be 0.01.

If the panel is located in the MCR and in the same general proximity to the MCR staff as the MCB, then a non-suppression factor of 0.02 should be used. The remaining panels in the MCR should be treated using a non-suppression factor of 0.01.

The extent of internal fire damage within a panel given the presence of an ASD requires further guidance. If suppression is successful, then the fire would still be in its incipient phase and no damage beyond the ignition source should be considered. If the fire is not suppressed, then the postulated fire should be assumed to grow and be treated using the existing guidance in NUREG/CR-6850.

3. Electrical Cabinet in a Non-Continuously Occupied Location – The current guidance in NUREG/CR-6850 recommends that a FPRA treat the presence an in-cabinet smoke detector by considering the availability of an alarm before it would have otherwise been detected by other means. The guidance states that this 'advance' warning would occur during an assumed 5 minute incipient period. If the panel is in a location that is not continuously occupied, then the guidance provided in NUREG/CR-6850 recommends the use of the prompt suppression characteristics consistent with Welding bin in Table P-3 of NUREG/CR-6850. The manual suppression characteristics have been modified as documented in FAQ 08-0050 (Supplement 1) and the values in Table 14-1 should be used instead. The five minutes of available incipient time translates to a probability of 0.39. Adding the screening hardware failure probability of 0.01 from FAQ 08-0046 yields a non-suppression probability of 0.40. Given that the presence of an ASD system would provide more than 5 minutes of 'warning', a lower value should be used.

   The development of a recommended value for this case uses the same approach used in the prior two cases. The result of a sensitivity study as the value of the additional delay varies is provided below.

Non-Continuously Occupied Location	
ASD Detection Credit (min.) [1]	Non-Suppression Probability

0	0.40
5	0.16
10	0.07
15	0.03
20	0.02
25	0.01
30	0.01

Note 1: The time duration refers to the additional time warning provided by the ASD system as compared to a traditional non-aspirating smoke detector

The recommended treatment for this case uses the same approach as above. The response of the plant staff to a fire outside the MCR would be similar to that which would occur for a main control room panel that is not in the general proximity to the MCR staff as the MCB. This results in a non-suppression probability of 0.03.

The extent of internal fire damage within a panel given the presence of an ASD requires further guidance. If suppression is successful, then the fire would still be in its incipient phase and no damage beyond the ignition source should be considered. If the fire is not suppressed, then the postulated fire should be assumed to grow and be treated using the existing guidance in NUREG/CR-6850.

4. Area-Wide Applications – The existing guidance in Appendix P of NUREG/CR-6850, recommends the treatment of high-sensitivity smoke detectors by crediting the prompt suppression response. The guidance recommends the use of the Welding bin from Table P-3 of NUREG/CR-6850. The manual suppression characteristics have been modified as documented in FAQ 08-0050 (Supplement 1) and the values in Table 14-1 should be used instead. Unlike the prior cases addressed in this FAQ, the application of an ASD system in an area-wide application introduces an additional layer of complexity in that the specific location (i.e., the source panel/cabinet) may not be readily apparent. In that case, it may not be until the fire has actually grown beyond the incipient phase (i.e., until it has entered the active burning/growth phase) that its location becomes apparent. Given this consideration, no credit is assumed in this FAQ for suppression to advert damage within a panel or other ignition source that is the origin of the assumed fire. Instead, this FAQ focuses on a recommended treatment that builds on the existing guidance in NUREG/CR-6850 for preventing fire propagation beyond the fire origin.

If an area-wide ASD system is present, then as noted in NUREG/CR-6850, the prompt suppression characteristics (using the Welding bin) can be used to model the suppression response for all postulated fire scenarios except those involving HEAFs. No specific treatment for suppression to advert internal panel damage or damage to the ignition source itself is proposed. Therefore, all cases should assume unspecified internal panel fire damage. For

non-electrical panel (cabinet) fires, the ignition source should be assumed damaged. Further fire propagation beyond the ignition source is treated using the appropriate fire growth rate described in NUREG/CR-6850 or FAQ 08-0052 in Supplement 1.

An initial bounding treatment for electrical panels (cabinets) can be used that assumes the responding fire brigade has no practical ability to ascertain the location of the fire until active burning (the growth phase) has occurred. Using a λ of 0.188 from Table 14-1 and the 12 minute fire growth rate produces a suppression failure probability of 0.10. The addition of a hardware failure probability of 0.01 as noted in FAQ 08-0046 results in a recommended value of 0.11. However, as noted in the FAQ 08-0046 and this FAQ, once the fire brigade has arrived at the fire location, there is possible overlap between the detection capability of the ASD system and the ability of a human to 'detect' the same event. FAQ 08-0046 also notes that the treatment of ASD is limited to providing an hour of 'advance' warning. This would mean that even with a possible delay in fire brigade response, a notable amount of time would be available for the responding fire brigade to identify the location of the fire. Because of uncertainty in the treatment of this variable, a sensitivity study was performed.

Remaining Incipient Time (min.)	Growth Time (min.)	Total Time (min.)	Non-Suppression Probability
0	12	12	0.11
5	12	17	0.05
10	12	22	0.03
15	12	27	0.02
20	12	32	0.01
25	12	37	0.01
30	12	42	0.01

The sensitivity results show that if the postulated fire has started its growth phase at the time of fire brigade arrival, then the appropriate credit would be a non-suppression probability of 0.11. Assuming an hour for fire brigade response would be unreasonably conservative. If instead, it is assumed that 30 minutes is required for brigade response and they are able to locate the fire within the next 15 minutes, then the remaining time for non-suppression would be 60 – 30 – 15 + 12 = 27 minutes:

$$e^{-\lambda t} = e^{-0.188*27} + 0.01 \sim 0.02$$

However, if the location has few (10 or less) electrical cabinets, it would be reasonable that the brigade would be able to quickly isolate the location of the fire. If instead of 15 minutes, 10 minutes was needed to determine the fire location, the resulting non-suppression probability would be:

$$e^{-0.188*32} + 0.01 \sim 0.01$$

Based on the results of the sensitivity study, the following treatment is recommended.

1. If the area-wide incipient detection credit is applied to a location within the power block and the location has 10 or less electrical cabinets, the non-suppression credit to prevent fire propagation should be 0.01.

2. If the area-wide incipient detection credit is applied to a location within the power block and the location has more than 10 but less than 30 electrical cabinets, the non-suppression credit to prevent fire propagation should be 0.02.

3. If the area-wide incipient credit is applied to a location with more than 30 electrical cabinets or that can be expected to experience extended time for fire brigade response (e.g., remote buildings) or if the location of the panel fire is not readily accessible within the area, the non-suppression credit to prevent fire propagation should be 0.05.

Failure to suppress the fire should be treated using the existing available guidance.

For non-electrical panel (cabinet) fires, the existing guidance provided in NUREG/CR-6850 should be used. This guidance recommends the use of the welding suppression curve (λ = 0.188). The time available for suppression should be determined using the appropriate growth rate and time to target damage.