FAQ Number: 14-0007 **FAQ Revision:** D

FAQ Title: Transient Fire Frequency Likelihood

Plant: Exelon: Peach Bottom, Limerick, & TMI **Date:** 3/11/2014

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Purpose of FAQ:

To propose an alternative methodology to distribute transient ignition frequencies (Bins 3, 5, 6, 7, 11, 24, 25, 31, 36, 37) that contains a more structured approach to accounting for influence factor variations within a PAU. Examples of variations include transient free zones and dedicated storage areas that only makeup part of a PAU.

Relevant NRC document(s):

NUREG/CR-6850

Details:

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

NUREG/CR-6850 Volume 2 Section 6.5.7.

Circumstances requiring interpretation or new guidance:

The current methodology involves the application of transient influence factor rankings to PAUs. Variations of the influence factors within PAUs are not addressed until calculating ignition frequencies for scenarios. Waiting to account for PAU variability until the scenario development task increases the complexity of that task and introduces more opportunities to misrepresent the transient ignition frequency for fire scenarios. An alternative approach is to evaluate transient influence factors for spaces smaller than fire compartments prior to the development of fire scenarios. The result is a more intuitive process for modeling variations of transient ignition frequency that will be easier to maintain and adjust in future fire PRA model updates.

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

None

Potentially relevant existing FAQ numbers:

NFPA 805 FAQ 12-0064, FPRA FAQ 13-0005

Response Section

Proposed resolution of FAQ and the basis for the proposal

The proposed resolution to the FAQ consists of revising the W_{GT}, N_{GT}, W_{WC}, and N_{WC} formulas provided in FAQ 12-0064 and enabling the assignment of Transient Influence Factors to areas of the plant that may be smaller than PAUs.

The basis of the alternative method is included below along with the specific modification to the necessary formulas.

1.0 CURRENT METHODOLOGY

For illustrative purposes the examples in this FAQ use the transient fire ignition frequency bins identified in NUREG/CR-6850 (listed in Table 1).

TABLE 1. TRANSIENT FIRE IGNITION FREQUENCY BINS

Bin	Generic Location	Description	NUREG/CR-6850 FIF
3	PWR Containment (COP)	General Transients and Hotwork (GT)	2.00E-03
5	Control/Aux/Reactor (CAR)	Cable Fires Cut & Weld (CF)	1.60E-03
6	Control/Aux/Reactor (CAR)	Transients Cut & Weld (WC)	9.70E-03
7	Control/Aux/Reactor (CAR)	General Transients (GT)	3.90E-03
11	Plant Wide (PW)	Cable Fires Cut & Weld (CF)	2.00E-03
24	Plant Wide (PW)	Transients Cut & Weld (WC)	4.90E-03
25	Plant Wide (PW)	General Transients (GT)	9.90E-03
31	Turbine Building (TB)	Cable Fires Cut & Weld (CF)	1.60E-03
36	Turbine Building (TB)	Transients Cut & Weld (WC)	8.20E-03
37	Turbine Building (TB)	General Transients (GT)	8.50E-03

NUREG/CR-6850 identified three main influence factors that affect the likelihood of a transient fire within an analysis unit. An enhancement to subdivide the maintenance influence factor into an additional hotwork influence factor was presented in NFPA 805 FAQ 12-0064 and is included in this discussion.

- Maintenance: Corrective and preventative
- Hotwork: How often welding or cutting are performed
- Storage: Permanent, and long temporary.
- Occupancy: How often personnel are present in the space.

All analysis units are assigned ranking values for each of the four transient fire influencing factor categories listed above. These influence factor ratings are used to establish a relative ranking of the PAUs by fire contributing activities. These ranking values are then used to develop weighting factors used to allocate the updated fire ignition frequencies to each analysis unit. Additionally, cable combustible loading is considered a modifier of the human activity factors above to establish PAU fire ignition frequencies for cable fires due to welding and cutting. The cable loading represents the exposure of cable to human activities that may result in fire damage.

NFPA 805 FAQ 12-0064, Table 6-3, provides a framework for this assignment and includes suggested influence factor ranking values. Table 2 provides a summary of the influence factor rankings, values and the applicable influence factors.

TABLE 2. TRANSIENT FIRE INFLUENCE FACTOR RANKINGS

Ranking	Value	Applicable Influence Factors
No	0	All
Extremely Low	0.1	Hot Work
Very Low	0.3	All
Low	1	All
Medium or Average	3	All
High	10	All
Very High	50	Maintenance, Hotwork

The numerical ranking of each influence factor for a PAU can be referred to using the following variables. These are used in equations presented below.

- $n_{M,J,L}$ = Maintenance Influence Factor for PAU “J” of generic location “L”
- $n_{H,J,L}$ = Hotwork Influence Factor for PAU “J” of generic location “L”
- $n_{O,J,L}$ = Occupancy Influence Factor for PAU “J” of generic location “L”
- $n_{S,J,L}$ = Storage Influence Factor for PAU “J” of generic location “L”

In addition to the Influence Factors identified above, the methodology calls for a cable loading location weighting factor ($W_{C,J,L}$) to be used in the calculation for Bins 5, 11, and 31. The factor is calculated by dividing the total amount of exposed cable in a PAU by the total amount in all PAUs assigned to the transient generic plant location (Equation 1):

$$W_{C,J,L} = \frac{\text{Amount of exposed cables in PAU J}}{\text{Amount of exposed cables in generic location L}} \quad (1)$$

The general transient frequency allocation weighting factor (W_{GT}) was applicable to transient fire Bins 3, 7, 25, and 37. The weighting factor was the sum of maintenance, occupancy, and storage influence factors normalized for the generic location. The mathematical representation of this computation is as follows:

$$W_{GT,J,L} = \frac{(n_{M,J,L} + n_{O,J,L} + n_{S,J,L})}{N_{GT,L}} \tag{2}$$

$$N_{GT,L} = \sum_i (n_{M,i,L} + n_{O,i,L} + n_{S,i,L}) \tag{3}$$

The transient fire caused by welding and cutting ignition frequency allocation weighting factor (W_{WC}) was applicable to Bins 6, 24, and 36. The methodology in NUREG/CR-6850 suggests using the maintenance influence factors to develop this weighting factor. However, FAQ 12-0064 proposes the use of the hotwork influence factor for this calculation. This better represents the likelihood of a transient fire caused by welding and cutting. The weighting factor was calculated as the hotwork maintenance influence factor normalized for the generic location. The mathematical representation of this computation is as follows:

$$W_{WC,J,L} = \frac{n_{H,J}}{N_{WC}} \tag{4}$$

$$N_{WC} = \sum_i n_{H,i,L} \tag{5}$$

The cable fire caused by welding and cutting ignition frequency allocation weighting factor (W_{CF}) was applicable to fire Bins 5, 11, and 31. The methodology in NUREG/CR-6850 suggests using the maintenance influence factors to develop this weighting factor. Consistent with the transient fire caused by welding and cutting the hotwork influence factor is used instead of the maintenance influence factor. The weighting factor was therefore the product of the hotwork influence factor and the PAU cable loading factor normalized for the generic location. The mathematical representation of this computation is as follows:

$$W_{CF,J,L} = \frac{n_{H,J,L} \times W_{C,J,L}}{N_{CF,L}} \tag{6}$$

$$N_{CF,L} = \sum_i \left(n_{H,i,L} \times W_{C,i,L}\right) \tag{7}$$

The PAU fire ignition frequencies are then calculated by multiplying the weighting factors by the total fire ignition frequency bin values as well as the generic location

weighting factor. The generic location weighting factor (W_L) is used to account for the number of units since the bin frequencies are based on a single unit. This paper assumes a single unit site and therefore the W_L is equal to 1.

$$\lambda_{IS,J} = \lambda_{IS} \times W_L \times W_{IS,J,L} \quad (8)$$

As transient based scenarios are developed, the frequencies are further distributed within PAUs. Ignition frequencies for floor based scenarios are distributed based on a floor area ratio which is described on page 11-2 of NUREG/CR-6850. Ignition frequencies for cable fires due to welding and cutting are likewise distributed based on the ratio of cables present. FPRA FAQ 13-0005 identifies exposed cable tray surface area as a valid method to apportion the transient cable fire frequencies.

$$\lambda_{scenario} = \lambda_{\mathrm{PAU}} \times \frac{(\text{Floor Area or Cables})_{\text{scenario}}}{(\text{Floor Area or Cables})_{PAU}} \quad (9)$$

2.0 AREAS OF ENHANCEMENT TO THE CURRENT METHODOLOGY

There are two enhancements to the current methodology that will be discussed further in this section. These insights were identified while developing fire PRAs at multiple nuclear power plants of varying designs. Based on these observations, these are universal and are not specific to a specific power plant or plant design.

2.1 Varying influence factor rankings within a PAU

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

2.2 Spatial geometry factor for floor based transients

This enhancement only applies to floor based transients; which includes general transients (Bins 3, 7, 25, and 37) and transient due to welding and cutting (Bins 6, 24, and 36). The distribution of the fire ignition frequencies for these bins to applicable PAUs does not currently consider spatial geometry. The only factors used to distribute the frequencies are the transient influence factors. If two PAUs are assigned the same set of influence factors, this treatment results in the PAUs being assigned equal floor based transient ignition frequencies. However, these two PAUs could be different in

size. This would not occur for cable fires due to welding and cutting (Bins 5, 11, 31), as these frequencies are calculated based on the amount of cables present. As a result, PAUs with equal hot work influence factors but different quantities of cable receive different cable fires due to welding and cutting frequencies.

The variation in frequency apportionment by transient fire type becomes more apparent if influence factors are assigned to spaces smaller than PAUs. Transient free zones and dedicated storage areas may represent a very small fraction of a PAU and therefore not considering the size of the spaces could significantly misrepresent the fire frequency distribution. Therefore, consideration of a spatial geometry factor for floor based transient fires should be addressed when assigning influence factors to spaces smaller than PAUs.

3.0 DETAILS OF PROPOSED ENHANCEMENTS

The proposed enhancements are not significant changes to the methodologies outlined in NUREG/CR-6850, NFPA 805 FAQ 12-0064, and FPRA FAQ 13-0005. The purpose of the enhancements is to provide an alternative approach that addresses variations of transient ignition frequency within a PAU prior to the scenario development task.

3.1 Assignment of influence factors to areas within PAUs

The current methodology does not look at spaces smaller than PAUs until the scenario development task. These spaces could alternatively be evaluated at the beginning of the transient ignition frequency calculation process. This involves assigning influence factors to Transient Ignition Source Regions (TISRs). TISRs may be PAUs or spaces smaller than PAUs based on the characteristics of the location. Examples of TISRs include PAUs, fire zones, rooms, transient free zones, dedicated storage areas, etc. TISRs should be based on administratively controlled areas to ensure that they are maintained by plant personnel.

The approach to calculating the ignition frequencies for TISRs is no different from that used above for PAUs except that the TISRs are assigned weighting factors instead of PAUs. The TISR approach allows PAUs to be defined without the need to consider how PAU selection will impact transient ignition frequency calculations.

When a transient scenario is developed within a TISR, the applicable floor area or quantity of exposed cable will be determined. This will be used to determine the fraction of the TISR fire ignition frequency that should be assigned to the scenario. This is shown in Equation 10.

$$\lambda_{scenario} = \lambda_{\text{TISR}} \times \frac{(\text{Floor Area or Cables})_{\text{scenario}}}{(\text{Floor Area or Cables})_{TISR}} \quad (10)$$

The concept of creating TISRs is applicable to all transient ignition frequency bins. However, as cable and floor based transient fires differ, so can their TISRs. Therefore, it is acceptable to have two sets of TISRs defined differently; one for each type of

Comment [A1]: The scope of this FAQ should be spaces within a PAU. FAQ 64 already addressed PAUs and the reductions in frequency that can be attained for a particular PAU. From your example below, it appears that the purpose of this FAQ is to enable an analyst to break up a PAU and credit a frequency different from the original PAU depending on how a section of a PAU is used.

Comment [A2]: Violations must be directly accounted for in this process. Violations of regions such as transient free zones do occur and are recorded. The amount of violations should affect the credit given.

transient fire. For example, the analyst may choose to define TISRs smaller than PAUs for floor based transients and maintain TISRs equal to PAUs for cable tray fires.

3.2 Addition of geometric factor to transient weighting factor calculations

As discussed in Section 2.2, the transient weighting factors for general transients and transients due to welding and cutting (see Equations 2-5) do not include consideration of the PAU floor areas. This approach differs from that used for cable fires due to welding and cutting in that for these types of fires, the amount of cables directly influence the cable fire weighting factor (see Equations 6-7). This results in differences in how the frequencies are apportioned. These differences become more apparent when the sizes of PAUs are significantly different or when the TISR approach is implemented.

Comment [A3]: For transients, a smaller PAU, once the transient frequencies have been allocated within, may produce smaller frequencies for every pinchpoint than a larger PAU of the same frequency (given comparable cable layouts). Yet, the frequency of the PAU or the TISR is not dependent on the floor area. See below for the factors which drive transient fire frequency for a PAU. The issue here is how should those frequencies be allocated within a PAU.

A more consistent approach is to include PAU floor area in the weighting factor calculations for floor based transient fires. As noted in Section 2.0 and shown in Equation 9, the use of a floor area ratio is already an accepted method of apportioning PAU transient frequencies to scenarios. In addition, the use of a parameter other than the influence factors was included in the cable fires due to welding and cutting weighting factor equations. Equation 11 defines the proposed floor area weighting factor for a PAU or TISR ($W_{A,J,L}$).

$$W_{A,J,L} = \frac{\text{Floor area in PAU/TISR J}}{\text{Floor area in generic location L}} \quad (11)$$

The floor area weighting factor would then be included in the W_{GT} and W_{CF} equations. Equations 2-5 would be replaced by Equations 12-15. Figure 1 depicts the current methodology and how the inclusions of the floor area weighting factor would be added to the process.

Comment [A4]: A small area may be configured such that it should have the same contribution to transient fire frequency as a large area. Rather than the size of the room, it's what's in the room that defines the maintenance factor; the foot traffic or need for continuous occupancy affects the occupancy factor; and the storage factor is more related to the function of the room. The cable tray fire frequency analysis linked two variables, maintenance and cables, since both needed to be present for the hot work cable fire. As indicated above, floor area has nothing to do with the frequency of fire of the TISR. Admittedly, the transient fire frequency may be concentrated in a PAU, but that is what this FAQ is supposed to address for certain TISRs within a PAU. Based on the above discussion, this approach does not appear consistent with the 6850 influence factors as described and as intended to be applied.

$$W_{GT,J,L} = \frac{(n_{M,J,L} + n_{O,J,L} + n_{S,J,L}) \times W_{A,J,L}}{N_{GT,L}} \quad (12)$$

$$N_{GT,L} = \sum_i \left[(n_{M,i,L} + n_{O,i,L} + n_{S,i,L}) \times W_{A,J,L}\right] \quad (13)$$

$$W_{WC,J,L} = \frac{n_{H,J} \times W_{A,J,L}}{N_{WC}} \quad (14)$$

$$N_{WC} = \sum_i \left(n_{H,i,L} \times W_{A,J,L}\right) \quad (15)$$

During the implementation of these equations previously assigned influence factor rankings should be reviewed to ensure that they were not influenced by the size of a

PAU. When including the floor area factor in the calculations, the influence factor rankings should consider the characteristics of the PAU/TISR per unit area.

3.3 Example of Alternative Methodology

This section provides an example on how the proposed methodology could be used in contrast to the existing methodology. In the example, PAU D contains three distinct spaces; a transient free zone, a dedicated storage area, and the rest of the PAU. These spaces may be separate fire zones, rooms, or simply well-defined administratively controlled spaces within the PAU. The example will show how floor based transient fire scenarios would be calculated within each space. As the methodology for cable fire due to welding and cutting is essentially the same, the associated factors are not included in the example. Tables 3A and 3B provide the PAU and TISR floor areas and transient influence factors.

TABLE 3A. PAU DATA

PAU	Floor Area [ft^2]	n_M	n_O	n_S	n_H
A	1000	3	3	3	1
B	500	3	3	3	1
C	800	1	3	1	3
D	1600	10	3	3	10
CAR Total	**3900**	**17**	**12**	**10**	**15**

TABLE 3B. TISR DATA

TISR	Floor Area [ft^2]	n_M	n_O	n_S	n_H
A	1000	3	3	3	1
B	500	3	3	3	1
C	800	1	3	1	3
D_TFZ	200	1	3	1	1
D_Storage	400	3	3	10	1
D_Other	1000	10	3	3	10
CAR Total	**3900**	**21**	**18**	**21**	**17**

Comment [A5]: There needs to be guidance on assigning influence factors in the TISR. For example, under what conditions and to what extent do the weighting factors assigned for D in Table 3a affect/constrain the factors assigned when breaking up D in Table 3b? For example, some assignments of influence factors for a PAU may not allow reduction of frequency within a section of the PAU upon taking measures within the PAU. Also, somewhere in this FAQ there should be a general discussion on how the assignment of influence factor(s) in the original PAU affects the credit you can get by breaking up the PAU into parts.

The first step is to calculate the weighting factors used in the transient ignition frequency calculations. Table 4A contains the weighting factors using the current methodology.

Table 4B provides a set of TISR weighting factors using the current equations as well as a set using the equations that include the floor area factor.

TABLE 4A. PAU WEIGHTING FACTORS

PAU	Current Methodology	
	W_{GT}	W_{WC}
A	0.23	0.07
B	0.23	0.07
C	0.13	0.20
D	0.41	0.67

TABLE 4B. TISR WEIGHTING FACTORS

TISR	Current Equations		Alternative Equations with Floor Area		
	W_{GT}	W_{WC}	W_{A}	W_{GT}	W_{WC}
A	0.15	0.06	0.26	0.22	0.07
B	0.15	0.06	0.13	0.11	0.03
C	0.08	0.18	0.21	0.10	0.17
D_TFZ	0.08	0.06	0.05	0.02	0.01
D_Storage	0.27	0.06	0.10	0.16	0.03
D_Other	0.27	0.59	0.26	0.39	0.69

Comment [A6]: Those PAUs which are not affected by the TSIR should not have their frequencies for general transient fires and welding/cutting fires affected, contrary to what this table implies when compared to table 4a, and what is implied in comparison of table 5a and 5b.

The next step is to calculate the fire ignition frequencies for each FIF bin. Table 5A again provides the results for the PAUs using the currently methodology. Table 5B includes frequencies for TISRs using the current and alternative equations.

TABLE 5A. PAU IGNITION FREQUENCIES

PAU	Current Methodology	
	Bin 7 (GT)	Bin 6 (WC)
A	9.00E-04	6.47E-04
B	9.00E-04	6.47E-04
C	5.00E-04	1.94E-03

D	1.60E-03	6.47E-03
CAR Total	**3.90E-03**	**9.70E-03**

TABLE 5B. TISR IGNITION FREQUENCIES

TISR	Current Equations		Alternative Equations with Floor Area	
	Bin 7 (GT)	Bin 6 (WC)	Bin 7 (GT)	Bin 6 (WC)
A	5.85E-04	5.71E-04	8.58E-04	6.69E-04
B	5.85E-04	5.71E-04	4.29E-04	3.34E-04
C	3.25E-04	1.71E-03	3.81E-04	1.61E-03
D_TFZ	3.25E-04	5.71E-04	9.54E-05	1.34E-04
D_Storage	1.04E-03	5.71E-04	6.10E-04	2.68E-04
D_Other	1.04E-03	5.71E-03	1.53E-03	6.69E-03
PAU D Total	**2.41E-03**	**6.85E-03**	**2.23E-03**	**7.09E-03**
CAR Total	**3.90E-03**	**9.70E-03**	**3.90E-03**	**9.70E-03**

Comment [A7]: In addition, PAU D general transients and welding/cutting should have the same frequency as in table 5a. You can redistribute frequencies in three new TISRs making up PAU D, but PAU D frequency must be the same in table 5a and 5b for each of these contributions.

The final step in the process is to distribute the PAU or TISR frequencies to the corresponding scenarios. Table 6 provides the scenario specific data for 3 scenarios postulated in PAU D.

TABLE 6. SCENARIO DATA

Scenario	Floor Area [ft^2]	PAU Ratio	TISR Ratio
D_TFZ	100	6.25E-02	5.00E-01
D_Storage	100	6.25E-02	2.50E-01
D_Other	100	6.25E-02	1.00E-01

The resulting scenario ignition frequencies are easily calculated using Equations 9 or 10 depending on if PAUs or TISRs are used. Table 7A contains the scenario ignition frequencies calculated directly using the equations included in NUREG/CR-6850. As this table shows, without adding additional factors at this point in the process the transient ignition frequencies for each type of scenario are equal. A factor could be applied to the TFZ scenarios to account for the reduced likelihood of transient fires. For example, a factor of 0.25 could be used and result in a frequency of 1.26E-4. However, the factor of 0.25 does not have a clear basis and the remaining 75% of the frequency no longer applied to the TFZ scenarios should be applied to the other scenarios. These limitations can be deterrents to accounting for variations of transient likelihood.

Table 7B shows scenario frequencies calculated based on TISRs using both the current equations and alternative equations that consider floor area. The use of TISRs and the

current equations do not provide the desired outcome. As it can be seen in Table 7B, the likelihood of a floor based transient fire in the TFZ is calculated to be higher than in the storage area. This seems counter intuitive since the influence factors are generally higher for the storage area than for the TFZ. The results are due to the different fractions of TISR floor area the transient scenarios represent. Using the alternative equations that consider floor area throughout the ignition frequency process, the scenario frequencies appear more in line with what would be expected given the input parameters.

TABLE 7A. PAU BASED SCENARIO FREQUENCIES

Scenario	Current Methodology		
	Bin 7 (GT)	Bin 6 (WC)	Scenario Total
D_TFZ	1.00E-04	4.04E-04	5.04E-04
D_Storage	1.00E-04	4.04E-04	5.04E-04
D_Other	1.00E-04	4.04E-04	5.04E-04

TABLE 7B. TISR BASED SCENARIO FREQUENCIES

Scenario	Current Equations			Alternative Equations with Floor Area		
	Bin 7 (GT)	Bin 6 (WC)	Scenario Total	Bin 7 (GT)	Bin 6 (WC)	Scenario Total
D_TFZ	1.63E-04	2.85E-04	4.48E-04	4.77E-05	6.69E-05	1.15E-04
D_Storage	2.60E-04	1.43E-04	4.03E-04	1.53E-04	6.69E-05	2.19E-04
D_Other	1.04E-04	5.71E-04	6.75E-04	1.53E-04	6.69E-04	8.22E-04

3.4 Additional areas of research

Comment [A8]: At this point, the comments made above redirect the method. These research areas may no longer be germane.

Implementing the above enhancements should not present a significant burden as the enhancements are relatively straightforward. However, the analyst may encounter difficulty when determining the appropriate floor area for outdoor spaces. Using the entire area of the outdoor areas within the global analysis boundary could result in a significantly high value. This would heavily weight the outdoor PAU(s) and the majority of the Plant Wide (PW) transient ignition frequencies would be assigned to these areas. While it may be true that the majority of PW transients occur in outdoor areas, basing the ratio on the floor area may be inaccurate if the outdoor area considered is very large.

A potential solution to this issue would be to reevaluate the fires in the fire events database (FEDB) and separate the PW transient fires into two categories; PW indoors

and PW outdoors. Until this work is performed, another solution could be to only include the floor area of outdoor areas in which transient scenarios will be postulated. Another option could be to limit the floor area of outdoor PAUs to the total floor area of all indoor PW areas. However the outdoor floor area issue is addressed, it should be documented clearly and a valid basis be provided.

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