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

FAQ Title: Transient Fire Frequency Likelihood

Plant: Exelon: Various **Date:** 03/14/2018

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Purpose of FAQ:

To propose an enhancement to the existing methodology to distribute transient ignition frequencies (Bins 3, 6, 7, 24, 25, 36, 37) that contains a structured approach to account for variations within a PAU (Fire Compartment per NUREG/CR-6850).

Relevant NRC document(s):

NUREG/CR-6850, NUREG-2169

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 PAUs or 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

Response Section

Proposed resolution of FAQ and the basis for the proposal

The proposed resolution to the FAQ creates a new term, Transient Ignition Source Regions (TISRs), to describe regions smaller than a PAU. TISRs may be postulated for spaces that represent obviously different transient influence factor rankings from the remainder of the PAU. The clearest example are functionally different spaces within a PAU that display a different likelihood of transient fires. For example, TISRs would justifiably be assigned to areas within a PAU if the PAU contained areas such as Transient Free Zones or a spaces dedicated to storage of materials providing the remainder of the PAU demonstrates significantly different characteristics for transient fire frequency. On the other hand, a TISR should not be specified simply because foot traffic from nuclear plant personnel is expected to be less in one area of the PAU than another area of the same PAU, say for example in a corner of a PAU. It should be noted that certain differences which affect transient frequency within a PAU must be evaluated on a case by case basis to determine if the PAU can be divided into TISRs. For example, a remote area in a PAU isolated by an obstruction such as a floor-to-ceiling stack of cable trays may warrant creating TISRs. In general, TISRs should be supported by plant procedures[1] or physical characteristics such as barriers/obstructions, and the proposed TISR areas within the PAU assessed to determine if the maintenance, hot work, occupancy, or storage influence factor rankings are different enough from the overall PAU itself to warrant defining TISRs.

This FAQ describes how to vary the fire ignition frequency for a TISR for the following ignition sources: 1) general transient fires and 2) transient fires caused by welding and cutting. As a part of this task, W_{GT}, N_{GT}, W_{WC}, and N_{WC} formulas provided in FAQ 12-0064 are revised for evaluating these fire ignition sources; enabling the assignment of Transient Influence Factors to areas of the plant that are smaller than PAUs, i.e., TISRs.

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

[1] Plant procedures that affect the assignment of transient influence factor rankings. Examples include procedures that control hot work, control storage, limit transient combustible packages, limit transient ignition sources, or limit the occupancy of an area (e.g. contamination, radiation, security).

1.0 CURRENT METHODOLOGY

For illustrative purposes the examples in this FAQ use transient fire ignition frequency bins 36 and 37 included in NUREG -2169 (listed in Table 1).

TABLE 1. RELEVANT TRANSIENT FIRE IGNITION FREQUENCY BINS

Bin	Generic Location	Description	NUREG-2169 FIF
3	PWR Containment (COP)	General Transients and Hotwork (GT)	4.21E-04
6	Control/Aux/Reactor (CAR)	Transients Cut & Weld (WC)	4.44E-03
7	Control/Aux/Reactor (CAR)	General Transients (GT)	3.33E-03
24	Plant Wide (PW)	Transients Cut & Weld (WC)	4.79E-03
25	Plant Wide (PW)	General Transients (GT)	8.54E-03
36	Turbine Building (TB)	Transients Cut & Weld (WC)	4.67E-03
37	Turbine Building (TB)	General Transients (GT)	6.71E-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. User of this FAQ should consult FAQ 12-0064 for guidance in using these influence factors, including the impact of violation controls and a performance monitoring program.

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"

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:

$$W_{GT,J,L} = \frac{(n_{M,J,L} + n_{O,J,L} + n_{S,J,L})}{N_{GT,L}} \quad (1)$$

$$N_{GT,L} = \sum_i (n_{M,i,L} + n_{O,i,L} + n_{S,i,L}) \quad (2)$$

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:

$$W_{WC,J,L} = \frac{n_{H,J,L}}{N_{WC}} \quad (3)$$

$$N_{WC,L} = \sum_i n_{H,i,L} \quad (4)$$

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.

$$\lambda_{IS,J} = \lambda_{IS} \times W_L \times W_{IS,J,L} \quad (5)$$

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. The distribution of frequencies to scenarios uses Equation 6 where n_A is the floor area factor.

$$\lambda_{scenario} = \lambda_{\text{PAU}} \times \frac{n_{A,Scenario}}{n_{A,PAU}} \quad (6)$$

2.0 AREA OF ENHANCEMENT TO THE CURRENT METHODOLOGY

As discussed, the current methodology applies transient influence factors to PAUs. However, it is likely that variations in the levels of maintenance, occupancy, storage, and hotwork 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.

3.0 DETAILS OF PROPOSED ENHANCEMENT

The proposed enhancement is a change to the methodologies outlined in NUREG/CR-6850 and NFPA 805 FAQ 12-0064 as applied to a subset of a PAU. The proposed enhancement is to provide an approach that addresses variations of transient ignition frequency within a PAU during the fire ignition frequency task.

3.1 Assignment of influence factors to areas within PAUs

The enhancement to the current methodology involves assigning influence factors to Transient Ignition Source Regions (TISRs). TISRs are spaces smaller than PAUs that are identified to have varying transient ignition frequency characteristics. Examples of TISRs may include 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.

Fire ignition frequencies for general transient fires and for transient fires from welding and cutting are dependent on the weighting factors for maintenance, occupancy, storage, and hot work. Floor area is introduced into the factor (TISRF, see Equations 7 and 8 below) to avoid diluting the transient frequency of individual ignition sources for larger TISR areas, and to avoid overemphasizing this frequency of individual ignition sources for smaller TISR areas. This FAQ recognizes that the approach for locating ignition sources, grouping transient fire scenarios, and as a result assigning transient fire frequency to ignition sources in a TISR may vary depending on room configuration and transient ignition source ZOI to efficiently evaluate fire risk.

The approach to calculating the ignition frequencies for TISRs first involves assigning transient influence factor rankings to the TISRs in a similar manner to that performed for PAUs. The next step is to identify the size of each TISR. The size should be based on the available floor area for floor based transient fires. The next step is to determine the Transient Ignition Source Region Factors (TISRFs) using Equations 7 and 8 where $n_{A,k,J}$ is the available floor area in TISR "k", within PAU "J".

$$TISRF_{GT,k,J} = \frac{(n_{M,k,J} + n_{O,k,J} + n_{S,k,J}) * n_{A,k,J}}{\sum_k [(n_{M,k,J} + n_{O,k,J} + n_{S,k,J}) * n_{A,k,J}]} \tag{7}$$

$$TISRF_{WC,k,J} = \frac{n_{H,k,J} * n_{A,k,J}}{\sum_k n_{H,k,J} * n_{A,k,J}} \tag{8}$$

The final step to calculate ignition frequencies for TISRs is to multiply transient bin PAU frequency by the applicable TISRF. This is depicted in Equation 9 where p represents the applicable transient fire type (i.e. GT, WC).

$$\lambda_{p,k} = \lambda_{p,J} * TISRF_{p,k,J} \tag{9}$$

As a result of this definition of the TISRF, the ignition frequency of a PAU is conserved upon the division of a PAU into TISRs.

The scenario frequencies are calculated in the same manner as they were without TISRs except that the floor area ratio calculated is based on the TISR rather than the PAU. If a scenario includes multiple TISRs, the applicable frequencies for each TISR are calculated and then summed to arrive at a total scenario frequency.

$$\lambda_{scenario} = \lambda_{\text{TISR}} \times \frac{n_{A,Scenario}}{n_{A,\text{TISR}}} \tag{10}$$

The concept of creating TISRs is applicable to all transient ignition frequency bins. How ever, as 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 transient fire.

3.2 Example of Alternative Methodology

This section provides an example on how the proposed methodology could be used. In the example, PAU D contains three distinct spaces; a transient free zone, a dedicated storage area, and the remainder of the PAU. These spaces may be separate fire zones, rooms, or simply well-defined spaces within the PAU. The example will show how floor based transient fire scenarios would be calculated within each space. Tables 3 and 4 provide the PAU and TISR floor areas and transient influence factors. Table 5 presents the PAU frequencies.

TABLE 3. 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	3	3	3	3
D	2000	10	3	10	3
TB Total	**4300**	**19**	**12**	**19**	**8**

TABLE 4. TISR DATA

TISR	Floor Area [ft^2]	n_M	n_O	n_S	n_H
D_TFZ	200	1	3	1	1
D_Storage	400	1	3	10	1
D_Other	1400	10	3	3	3

TABLE 5. PAU FREQUENCIES

PAU	Ignition Frequency		
	GT (Bin 37)	WC (Bin 36)	Total
A	1.21E-03	5.84E-04	1.79E-03
B	1.21E-03	5.84E-04	1.79E-03
C	1.21E-03	1.75E-03	2.96E-03
D	3.09E-03	1.75E-03	4.84E-03

The TISRFs are presented in Table 6 along with the corresponding ignition frequencies for each TISR with and without the proposed enhancement, whereby the frequency of the base case (compared to the enhancement) is the frequency assigned to each TISR of PAU D based on the fraction of floor area of each TISR. This comparison provides some insights with respect to the n_m, n_o, n_s, and n_H contribution to the TISRF (Illustration #1). In particular, the frequencies for the transient free zone and storage area TISRs are reduced based on the lower influence factor rankings compared to the 3rd TISR. As the methodology is setup to preserve the PAU frequencies, the frequency for the 3rd TISR increases.

TABLE 6. TISR FREQUENCIES - ILLUSTRATION #1

TISR	Fraction Floor Area of PAU	TISR Frequency Based On Floor Area Alone	TISRF		TISR Frequencies				Percent Change
			GT	WC	GT	WC	Total	% of PAU	
D_TFZ	10%	4.84E-04	0.03	0.04	1.06E-04	7.30E-05	1.79E-04	3.7%	-63%
D_Storage	20%	9.68E-04	0.19	0.08	5.96E-04	1.46E-04	7.42E-04	15.3%	-23%
D_Other	70%	3.39E-03	0.77	0.88	2.38E-03	1.53E-03	3.92E-03	81.0%	+16%

Table 7 shows the TISR frequencies for the same choice of floor areas and n_m, n_o, n_s, and n_H, whereby the comparison with and without the proposed enhancement is done with respect to the floor areas (Illustration #2). As expected, the reduction in frequencies due to floor area is largest for the TISR with the smallest floor area, and the reduction gradually decreases as the floor area increases. The TISR Frequencies from Table 6 are repeated in Table 7 for comparison purposes; the TISRF values for GT and WC which establish the "TISR Frequencies" are not repeated in Table 7.

TABLE 7. TISR FREQUENCIES - ILLUSTRATION #2

	TISRF Based On n_m, n_o, n_s, and n_H Factors Alone		TISR Frequencies Based On n_M, n_O, n_S, and n_H Factors Alone				TISR Frequencies (Repeated from Table 6)		Percent Change
	GT	WC	GT	WC	Total	% of PAU	Total	% of PAU	
D_TFZ	0.14	0.20	4.41E-04	3.50E-04	7.91E-04	16.3%	1.79E-04	3.7%	-77%
D_Storage	0.40	0.20	1.23E-03	3.50E-04	1.58E-03	32.7%	7.42E-04	15.3%	-53%
D_Other	0.46	0.60	1.41E-03	1.05E-03	2.46E-03	50.9%	3.92E-03	81.0%	+59%

In summary, although the set of factors (n_m, n_o, n_s, and n_H) and floor area are not independent in the equation for TISRF, these examples demonstrate trends consistent with that expected. The "TISR Frequencies Based On n_m, n_o, n_s, and n_H Factors Alone" (excluding floor area consideration) in Table 7 and the "TISR Frequency Based on Floor Area Alone" in Table 6 are only provided for illustrative purposes and are not acceptable methods for treating TISRs. Only the TISR frequencies derived from Equations 7, 8 and 9, which in both Tables 6 and 7 are listed as "TISR Frequencies," constitute the results from the proposed method enhancement described in this FAQ.

3.3 Impact of TISR Approach on Fire Scenarios

Since a TISR does not confine the effects of a fire, it should be noted that an ignition source may damage a target located in a different TISR. Also, since a single target may overlap several TISRs, a single target may be damaged from several sources from different TISRs. Thus, when applying the TISR for general transients and transients from welding and cutting as in Section 3.1 these impacts must be taken into account to develop the fire scenarios and evaluate the risk.

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