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

FAQ Title: Transient Fire Frequency Likelihood

Plant: Exelon: Various **Date:** 1/10/2017

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Purpose of FAQ:

To propose an enhancement to the existing methodology to distribute transient ignition frequencies (Bins 3, ~~5~~, 6, 7, ~~11,~~ 24, 25, ~~31,~~ 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

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, ~~FPRA FAQ 13-0005~~

Response Section

Proposed resolution of FAQ and the basis for the proposal

The proposed resolution to the FAQ <u>creates a new term, Transient Ignition Source Regions (TISRs), to describe regions smaller than a PAU. This FAQ describes how to vary the fire ignition frequency for a TISR for the following ignition sources: 1) general transients and 2) transients from welding and cutting. As a part of this task,</u>~~consists of revising the~~ W_{GT}, N_{GT}, W_{WC}, and N_{WC} formulas provided in FAQ 12-0064 <u>are revised for evaluating these fire ignition sources;</u> ~~and~~ enabling the assignment of Transient Influence Factors to areas of the plant that <u>are</u>~~may be~~ smaller than PAUs<u>, i.e. TISRs</u>.

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 transient fire ignition frequency bins 6 and 7 included 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. Users of this FAQ should consult FAQ 12-0064 for guidance in using these influence factors, including the impact of violation of 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”
- ~~$n_{C,J,L}$ = Cable Loading 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):

$$W_{C,J,L} = \frac{n_{C,J,L}}{\sum_i n_{C,i,L}} \tag{1}$$

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:

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

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

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:

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

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

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. The distribution of frequencies to scenarios uses Equation 9 where n_A is the floor area factor and n_C is the cable loading factor.

$$\lambda_{scenario} = \lambda_{PAU} \times \frac{n_{A,Scenario}}{n_{A,PAU}} \text{ or } \frac{n_{C,Scenario}}{n_{C,PAU}} \quad (9)$$

Commented [HJ1]: N sub c should be removed from eq 9 as the revision does not affect this term.

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.

Commented [HJ2]: Are fire zones subsets of a PAU?

3.0 DETAILS OF PROPOSED ENHANCEMENT

The proposed enhancement is a change to the methodologies outlined in NUREG/CR-6850, NFPA 805 FAQ 12-0064 as applied to a subset of a PAU, and FPRA FAQ 13-0005. 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 ~~not only to the PAUs, but also~~ 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.

> **Commented [HJ3]:** Section 3.1 is on assigning influence factors to areas smaller than a PAU. Adjust first sentence to be consistent with overall section.

> **Commented [HJ4]:** Are fire zones smaller than PAUs?

The basis behind the TISR methodology for general transient fires and for transient fires from welding and cutting, which allows the influence factors to be weighted by floor area, is that a grid is established to determine the number and location of transients for a TISR. Due to the grid, a TISR with a larger floor area will contain a larger number of transients than a TISR with a smaller floor area. To apply this FAQ, the number of grid spaces across different TISRs should be proportional to the floor area of the different TISRs. The application of this FAQ ensures that the transient frequency is not diluted for larger areas due to the grid, and is not overemphasized for smaller areas. Thus to apply this FAQ, grids proportional to the floor area must be applied to evaluate the importance of transients for the fire frequency ignition bins of general transients and to evaluate transients from welding and cutting.

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 and the amount of exposed cables for floor based transient fires and cable tray fires respectively. The next step is to determine the Transient Ignition Source Region Factors (TISRFs) using Equations 10, or 11~~, or 12~~ where $n_{A,k,J}$ is the available floor area ~~and $n_{C,k,J}$ is the amount of exposed cable~~ in TISR "k", within PAU "J".

$$TISRF_{GT,k,J} = \frac{(n_{M,k,J} + n_{O,k,J} + n_{S,k,J}) * n_{A,k,J}}{\sum_k [(n_{M,k,J} + n_{O,k,J} + n_{S,k,J}) * n_{A,k,J}]} \quad (10)$$

$$TISRF_{WC,k,J} = \frac{n_{H,k,J} * n_{A,k,J}}{\sum_k n_{H,k,J} * n_{A,k,J}} \quad (11)$$

~~$$TISRF_{CF,k,J} = \frac{n_{H,k,J} * n_{C,k,J}}{\sum_k n_{H,k,J} * n_{C,k,J}} \quad (12)$$~~

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 13 where p represents the applicable transient fire type (i.e. GT, WC~~, CF~~).

$$\lambda_{p,k} = \lambda_{p,J} * TISRF_{p,k,J} \tag{13}$$

The scenario frequencies are calculated in the same manner as they were without TISRs except that the floor area ~~or cable~~ 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.

$$\lambda_{scenario} = \lambda_{\mathrm{TISR}} \times \frac{n_{A,Scenario}}{n_{A,\mathrm{TISR}}} \text{ or } \frac{n_{C,Scenario}}{n_{C,\mathrm{TISR}}} \tag{14}$$

Commented [HJ5]: Need to adjust eq. 14. Need to remove "or" and ratio including n sub c from equation

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 transient fire. ~~For example, the analyst may choose to define TISRs for floor based transients and not for cable tray fires.~~

Commented [HJ6]: Are you saying that administrative controls could be placed on hot work and not general transients for example, thus warranting different TISRs for the two ignition sources?

3.2 Example of Alternative Methodology

Commented [HJ7]: Our understanding is that the example only applies to general transients, and transients from welding and cutting. As long as this is a correct understanding, the staff has no comment on the example.

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. ~~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 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	1	3	1	3
D	2000	10	3	10	3
CAR Total	**4300**	**17**	**12**	**17**	**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

TABLE 4. TISR DATA

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

TABLE 5. PAU FREQUENCIES

PAU	Ignition Frequency		
	GT (Bin 7)	WC (Bin 6)	Total
A	7.63E-04	1.21E-03	1.98E-03
B	7.63E-04	1.21E-03	1.98E-03
C	4.24E-04	3.64E-03	4.06E-03
D	1.95E-03	3.64E-03	5.59E-03

The TISRFs are presented in Table 6 along with the corresponding ignition frequencies for each TISR. The table also calculates the distribution of the PAU frequency to each TISR with and without the proposed enhancement. Without accounting for the influence factor variations the distribution of transient frequency would have simply been based on the floor area ratios. 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

TISR	Fraction Floor Area of PAU	Frequency Without TISR Method	TISRF		TISR Frequencies				Percent Change
			GT	WC	GT	WC	Total	% of PAU	
D_TFZ	10%	5.59E-04	0.03	0.04	6.72E-05	1.52E-04	2.19E-04	4%	-61%
D_Storage	20%	1.12E-03	0.19	0.08	3.77E-04	3.03E-04	6.80E-04	12%	-39%
D_Other	70%	3.91E-03	0.77	0.88	1.51E-03	3.18E-03	4.69E-03	84%	+20%

Commented [HJ8]: The comparison below is misleading. Without the TISR method, PAU D cannot be divided into parts, and thus column 3 is incorrect. The proper comparison would be to compare the TISR frequencies with the floor area weighting with the frequencies acquired by using the influence factors without the floor weighting factors.

3.3 TISR for Cable Fires from Welding and Cutting

TISRs can be established for subsets of a PAU for the ignition source, cable fires from welding and cutting. That is, the PAU can be divided into parts. However, the above description of TISRs is silent on this ignition source since the weighting factor which utilizes the influence factors to establish the frequency per TISR is that in NUREG/CR-6850 and FAQ 12-0064. Thus, the weighting factor for cable fires from welding and cutting does not contain the floor area (therefore the influence factors are not weighted by the floor area), contrary to that for TISRs for general transients and for transient fires from cutting and welding. Once the fire ignition frequency for the TISR is established, FAQ 13-0005 is applied to evaluate the risk for the TISR, refining the fire scenarios as appropriate.

3.4 Impact of TISR Approach on Fire Scenarios

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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. With respect to Section 3.3 for cable fires from welding and cutting, the cable tray assumed damaged when applying FAQ 13-0005 (determining CCDP in Steps 2 and 3 of FAQ 13-0005 on First and Subsequent Screenings) must be selected from the entire TISR, including cable trays that extend into the TISR from another TISR. Note that FAQ 13-0005 stipulates that damage is limited to a single tray from cable fires from welding and cutting, and thus fire does not propagate from tray to tray from these fires. This assumption of no propagation does not apply to fires from general transients and fires due to transients from welding and cutting, and thus propagation may occur for these fires.

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3.33.5 Additional areas of research

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 floor area for outdoor TISRs. A potential solution to this issue could be to only include the floor area of outdoor areas in which transient scenarios are postulated. However the outdoor floor area issue is addressed, it should be documented clearly.

Commented [HJ9]: From the title of this section, more work is needed to figure out how to apply to outside areas. Absent more detailed guidance, I suggest we add a statement that future work will address this topic, but outside areas is outside the scope of the current TISR approach.

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