FAQ Number 13-0006 **FAQ Revision** 0

FAQ Title Modeling Junction Box Scenarios in a Fire PRA

Plant: Various Date: May 6 2013

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Purpose of FAQ:

The purpose of this FAQ is twofold: 1) provide a definition for junction boxes that allow the characterization and quantification of junction box fire scenarios in plant locations requiring detailed Fire PRA/Fire Modeling analysis and 2) describe a process for quantifying the risk associated with junction box fire scenarios.

It should be noted that the junction box scenario selection and definition guidance described in this section applies to those fire zones requiring detailed fire modeling analysis only. The fire zones in the Fire PRA modeled as full compartment burn should already include the fire ignition frequency contribution of junction boxes that has been apportioned to the fire zone.

Relevant NRC document(s):
R.G. 1.200, Rev. 2; NUREG/CR-6850

Details:

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

Chapter 6 of NUREG/CR-6850

Circumstances requiring interpretation or new guidance:

Chapter 6 of NUREG/CR-6850 includes a generic fire ignition frequency for junction boxes. This classification of junction boxes as an individual ignition source was also previously included in the EPRI Fire PRA Implementation Guide (EPRI, TR-105928, 1995.) because selected fire events data listed junction boxes as the point of fire origin. The identification of junction boxes as ignition sources suggest that the Fire PRA should include the contribution of junction box fires in the risk quantification. However, there is no guidance in NUREG/CR-6850 for characterization, analysis and quantification of junction box fires. Guidance is only available in Chapter 6 of NUREG/CR-6850 for apportioning the generic fire ignition frequency to the plant partitioning elements within the scope of the Fire PRA.

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Specifically, Chapter 6 of NUREG/CR-6850 recommends in page 6-17 that “The number of junction boxes in an area may be difficult to determine. The frequency can be apportioned based on ratio of cable in the area to the total cable in the plant. Therefore, the ignition source-weighting factor of the cables may be used for this bin, as well.” This guidance is very similar if not identical to the apportioning guidance provided earlier by EPRI in the Fire PRA Implementation Guide (EPRI, TR-105928, 1995.). Notice that the guidance suggests that explicit count junction boxes is not necessary because the number of junction boxes can be estimated based on cable load.

Since NUREG/CR 6850 provides no guidance on how to represent the risk of junction box fire scenarios in fire zones receiving detailed fire modeling analysis, this FAQ provides an alternative to incorporate the risk contribution of such scenarios into the Fire PRA.

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

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Potentially relevant existing FAQ numbers:

None.

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Response Section:

Proposed resolution of FAQ and the basis for the proposal:

1.0 The Definition of Junction Box for Fire PRA Applications

Generally, a junction box is defined as a fully enclosed metal box containing terminals for joining or splicing cables. However, for the purpose of a Fire PRA, this definition must be expanded to clearly differentiate junction boxes from other electrical enclosures. The following characterization for junction boxes is therefore provided:

- The box must be fully enclosed with metal panels bolted or welded together but not necessarily well sealed per the definition for well sealed panels in Chapter 8 of Supplement 1 to NUREG/CR-6850.
- Cables entering or exiting the junction box should be in metal conduits and have mechanical connections to the metal box.
- The junction box should include only terminals for joining and splicing cables.
- Junction boxes may include some items excluded from the count of electrical cabinets if the excluded items meet the above criteria. In particular, the electrical cabinet counting guidance in NUREG/CR-6850 and Supplement 1 to NUREG/CR-6850 states that “simple wall-mounted panels housing less than four switches may be excluded from the counting process” and that “well-sealed electrical cabinets that have robustly secured doors (and/or access panels)… should be excluded from the

counting process." Most junction boxes will meet one or both of these exclusionary criteria. However, exclusion from counting as electrical cabinets does not automatically exclude an item from consideration as a junction box.

The above definition of junction boxes specifically excludes:

- Boxes containing electrical components other than terminal point or splice such as electronic equipment, relays, switches, breakers, etc should not be considered junction boxes.
- Metal enclosures with indication lights, display panels, switches, buttons, etc on the surface are not considered junction boxes.
- Simple wall-mounted panels housing less than four switches, cited previously, that do not meet the inclusionary criteria above are not junction boxes. Such items are small local alarm panels, intercom boxes, radio repeater boxes, emergency light boxes, and other similar small component enclosure boxes. These items are neither junction boxes nor electrical cabinets.
- Junction boxes containing high voltage circuits above 1000V that have cable splices, voltage connections or elbow style connections. These boxes should be only found in limited Fire PRA physical analysis units in the plant and should be treated as electrical cabinets.
- Electrical enclosures used only to route cables and have no connections, termination point or splices should not be treated as junction boxes for the purpose of the guidance provided in this analysis.
- Relatively large termination panels on the floor with high cable loading intended for joining and splicing cables. Specifically,
  - Similar to the "Electrical Cabinet" ignition source (i.e., Bin 15 in Chapter 6 of NUREG/CR-6850), these termination panels are easy to count and do not present the challenge of counting small junction boxes. Although it is recognized that the ability to count an ignition source is not part of its definition, it is included as a consideration because the classification of junction boxes intended to capture the risk of electrical enclosures that may not be visible to walkdown analysts are difficult to count. Consistently, the fire events classified as junction box for the calculation of generic frequencies do not include relatively large floor based termination panels. That is, the fire events data associated with relatively large floor based termination panels are classified as "electrical cabinets" in the generic ignition frequency model and should not be considered junction boxes.
  - Termination panels are typically characterized by high cable loading. Due to the relatively high cable loading, the cables are not routed in or out of the panels with

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conduits. Instead, cables drop into the panels from cable trays. This configuration is not consistent with the definition of a junction box described earlier.

- Relatively large Junction boxes or termination panels with doors, or openings, making the content of the panel easily accessible to plant personnel. The intent is to exclude from the junction box fires those events that would be initiated by plant personnel doing routine maintenance or inspection on them during power operation.

In summary, the definition above is intended to clearly differentiate junction boxes from electrical cabinets so that the process of identifying ignition sources in a physical analysis unit results in each electrical enclosure being categorized as belonging to one of three groups:

- Electrical cabinets that are included as Bin 15 in the Fire PRA model per the guidance in Chapter 6 of NUREG/CR-6850,
- Electrical cabinets that are excluded from the Fire PRA model per the guidance in Chapter 6 of NUREG/CR-6850, and Chapter 8 of Supplement 1 of NUREG/CR-6850. Examples of these include well sealed cabinets, and small wall mounted panels with less than 4 switches in the cover.
- Junction boxes as defined above are counted per the guidance in Chapter 6 of NUREG/CR-6850.

Note that some enclosures do not constitute electrical cabinets or junction boxes

2.0 Apportioning or Counting Junction Boxes

As mentioned earlier in this FAQ, Chapter 6 of NUREG/CR-6850 describes a process for apportioning the generic junction box frequency based on a consistent indicator for the amount of cable (e.g. cable loading, number of cables, cable lengths, etc) in the different physical analysis units within the scope of the Fire PRA.

This section describes another alternative for counting junction boxes for plants that have junction boxes as individual route points in the cable and raceway database system. For such situations, the cable and raceway database system can be “queried” for identifying and counting the junction boxes in each physical analysis unit. Notice that the terms “pull box”, “terminal box”, etc are often used in cable and raceway database systems for identifying junction boxes. This count can be used to apportion the generic frequency of junction boxes. Under this approach, the analyst should ensure that the database is current and that the definition of junction boxes counted from the cable and raceway database system is consistent with the one described earlier in this FAQ.

Two practical approaches for ensuring that the junction boxes meet the definition described in the previous section include:

1. Review plant specification documents describing the requirements for constructing and installing junction boxes if available, and/or
2. Conduct walkdowns in selected fire zones to sample junction boxes that are readily accessible (i.e. visible) and document the characteristics of the electrical enclosures that will be treated as junction boxes (i.e., these electrical enclosures that are not screened out as ignition sources, and not counted as part of other ignition frequency bins). The walkdowns should be conducted in some of the fire zones that are receiving detailed fire modeling analysis and junction box scenarios will be explicitely postulated.

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3.0 Background and Basis

Fire events in the EPRI Fire Events Database (FEDB) [1] were examined for historical experience and actual severity data in order to develop an improved methodology for handling these types of fires.

3.1 EPRI Fire Events Database / Industry Experience

The junction box events in EPRI's fire events database listed as challenging or undetermined are incident numbers 665, 745, and 1369. These events have the following descriptions:

- Incident No 665: A bad splice in junction box 529 caused an electric fire. A CO2 extinguisher was discharge and the power was removed from the cabling in the junction box. Cable splice (480 volt) failed in junction box. Electric arc burned hole in cover. De-energized electrical equipment.
- Incident No 745: Early warning detection alarmed in the control room in the auxiliary building, 752 level. This detection is below the fire area containing the fire source: Smoke travelled down a 4 inch conduit into the control room to set off the detector. Fire discovered inside junction box to fan motor. Aluminum cable connected to copper with single lug. Fan de-energized at breaker.
- Incident No 1369: Crimp in insulation on power cables at lug connection. Power cables/insulation burned. Confined to junction box on motor.

It is unclear if these events listed above happened in electrical enclosures matching the definition for junction boxes described earlier in this FAQ. Nevertheless, these event descriptions suggest that junction box fires can generate immediate damage to the content of the box (e.g. those events associated with electric arcs in junction boxes routing power circuits 480 V or higher); however, the damage was contained to the junction box itself.

3.2 Fire Experiments

A review of previous fire testing was conducted to identify information gained respective to junction box fires. No tests were found that investigated fires initiated in junction boxes specifically. However, one test series was identified which tested flame spread through conduits in fire barriers where junction boxes were used as termination points. This is applicable since one path for fire propagation from a junction box is through cable in conduit emanating from the junction box.

The Internal Conduit Seal Fire Test of One-Hundred One Electrical Conduit Penetrations was performed to determine minimum internal seal requirements for conduits to prevent spread of fire from one side of a rated fire barrier to the other. A test slab incorporated 101 conduit penetrations and was exposed to the ASTM E-119 standard fire exposure for 3 hours. Of the 101 tests performed 18 were conducted using junction boxes as termination points for the conduits on the unexposed side of the rated fire barrier. During the test, no flames propagated though the conduits and no cables were ignited on the unexposed side of the slab. The testing also illustrated the effect cable fill has on the performance of open conduits. The cables restricted the flow of hot gases and smoke and also acted as a heat sink. High Cable loadings (40%) acted as an effective internal penetration seal to the propagation of hot fire and hot gases. Based on the testing, guidelines were developed to address the propagation of fire though conduits. This testing concluded that conduits that terminate in junction boxes or other non-combustible closures need no additional internal sealing. This testing provides further evidence of the difficulty to propagate fires in a limited oxygen environment with metal conduits which have mechanical connections. The testing demonstrated the performance of junction boxes and cable filled conduits in limiting hot gas and flame propagation.

Given these test results, it is reasonable to assume that a fire initiating in a junction box would not spread via the cables in conduits. These tests support treatment of junction box-initiated fires as not spreading beyond the point of origin, as outlined in the following methodology.

4.0 Selection and Definition of Junction Box Fire Scenarios

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Junction box fires generally begin as relatively small fire or arc within the electrical enclosure. In most cases these fires do not generate enough heat to be self-sustaining and will self-extinguish prior to spreading outside. This is mostly due to the enclosed configuration of the box and in the cases of those scenarios where the integrity of the box is breached due to relatively low combustible content. In effect, this approach assumes that the zone of influence for these fires is equal to the junction box only. Consequently, the proposed approach provides a method for screening and analysis of such fires without the need for detailed fire growth, damage and suppression modeling.

Fire frequencies for a physical analysis unit are estimated using the methods described earlier in this FAQ. It should be noted that junction box frequencies, should be included for both thermoplastic and thermoset cables as the event experience suggests that these fires start due to small arcs generated by bad connections, which is not influenced by the cable insulation or jacket type. Once these frequencies are calculated for a given physical analysis unit, perform a screening process as follows.

Step 1: Preliminary Analysis:

1. For junction boxes that are Fire PRA targets, ~~C~~calculate the conditional core damage probability (CCDP) values assuming the loss (failure) of one junction box at a time in the physical analysis unit (i.e., never more than one junction is involved, and there is no sequential fire propagation from ~~one~~ the initiating ~~raceway~~ junction box to ~~another~~other intervening combustibles). Junction boxes explicitly listed in the cable and raceway database system should be associated with all the cables in the junction box. If junction boxes are not explicitly listed as route points in the cable and raceway database system, the analyst should calculate the CCDP for each route point (e.g., cable tray, conduits, etc) in the physical analysis unit.
2. Repeat the calculation for every ~~raceway~~ junction box located in the physical analysis unit that contains at least one Fire PRA target cable and compile and sort the values in a table. (Note that some junction boxes may not contain Fire PRA target cables.)

Step 2: First Screening Analysis:

1. Identify the junction box with the largest CCDP value (CCDPmax, J) and estimate the CDF for the physical analysis unit as the product of the physical analysis unit fire frequency (λIS,J) and CCPDmax,J.
    a. Check if the junction box is used to route cables only and has no connection, termination point or splices. Boxes with no connections, termination points or splices can be screened.
2. If this first screening level estimated CDF is low enough to meet PRA objectives, add this value to the physical analysis unit's total CDF and repeat this process for other physical analysis units~~-~~.
3. If the value is too large to meet PRA objective, conduct subsequent screenings as needed.

Step 3 Subsequent Screenings (optional)

1. Calculate (partition) the fire frequency applicable to the previously identified junction box (JB) (e.g., λJB1,J) used to arrive at the CCDP max, J above. Use a physical analysis unit- area ratio based on the plan view area of the target tray junction box to the total area of trays in the physical analysis unit (i.e., assume the junction box is uniformly located over the general surface area within the physical analysis unit) to apportion fire zone ignition frequency to a specific locaton within the zone.
2. Re-estimate a CDF value for the previously identified junction box (with the largest CCDP) as the product of the junction box-specific fire frequency (λJB1,J) and CCDPmax,J.
3. Identify the junction box with the second largest CCDP value (CCDPJB2,J), and calculate the CDF for the remainder of the physical analysis unit by assigning the remainder of the room frequency to that CCDP (CDF = ((λIS,J-λJB1,J)xCCDPnext,J). Notice that the fire frequency should be apportioned based on the guidance provided earlier in this section.
4. The modified physical analysis unit CDF is then the sum of these two sub-casesof the scenario involving the junction box with the highest CCDP (steps 3 items 1 & 2 above), and the scenario involving all other junction boxes, which is characterize by the junction box with the second highest CCDP (Step 3, item 3).
5. Repeat the subsequent screening techniques as needed, working junction box by junction box down through the CCDP list, until PRA objectives are met or until the refinement of the risk for these fires reaches the point of diminishing returns.

6. Note: As an alternative, junction boxes may be grouped based on similar CCDP values and treated in groups rather than as individuals. That is, the CDF for a group of junction boxes can be estimated as the group's combined fire frequency times the highest individual CCDP value among the group (but do not compound the CCDPs).

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7. It is recognized that some junction boxes will contain no Fire PRA cable targets. For such junction boxes, if it can be confirmed that failure of cables in one or more junction boxes would not cause a plant transient then, consistent with other aspects of the general Fire PRA methodology (e.g., qualitative screening1), those junction boxes can be treated as a group having an effective CCDP value of 0.0 and, as such, non-contributors to fire-induced CDF.

This The detailed process recommended in this FAQ is intended to drill down only until very small numbers are calculated and the analysis can stop. In the end, the estimated CDF is simply the sum of those cases split out in detail plus the balance applied to the next worst junction box in CCDP ranking table. Note that since the entire junction box is assumed damaged upon initiation of the fire, no credit for suppression to prevent overall junction box damage is allowed in this process.

References

1. Fire Event Database and Generic Ignition Frequency Model for U.S. Nuclear Power Plants. EPRI, 2001. TR-1003111.
2. EPRI Fire PRA Implementation Guide (EPRI, TR-105928, 1995.)
3. NUREG/CR 6850 (2005), "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2 Detailed Methodology," EPRI 1011989 Final Report, NUREG/CR-6850, Nuclear Regulatory Commission, Rockville, MD, September, 2005.
4. NUREG/CR 6850 Supplement 1 (2010), "Fire Probabilistic Risk Assessment Methods Enhancements Supplement 1 to NUREG/CR-6850 and EPRI 1011989," EPRI 1019259 Technical Report, NUREG/CR-6850 Supplement 1, Nuclear Regulatory Commission, Rockville, MD, September, 2010.

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

Not applicable. This is no current guidance beyond RG 1.200

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