Cable Fires Special Cases: Self-Ignited and Caused by Welding and Cutting

1 Background

In Appendix R of NUREG/CR-6850, a recommended approach is given in Section R.1 for addressing self-ignited cable fires and cable fires caused by welding and cutting. This approach involves postulating self-ignited fires and those cable fires caused by welding for rooms containing unqualified cables and calculating the intensity of the initial fire using a burning area consisting of the square of the tray width. An approach for characterizing the frequency of the postulated fire is also given utilizing cable mass ratios.

In practice, this approach can overestimate the size and intensity of the postulated fire. An example illustrating this issue is provided in this white paper. This overestimation creates larger and more quickly spreading fires in the Fire PRA. The large fires do not match the actual fire events found in the current database and may advance further in the analysis than warranted, meaning that significant effort may be wasted.

This white paper outlines a more practical and realistic approach in the Proposed Methodology section and suggests replacement text for Section R.1.

2 Proposed Methodology

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 low energy ignition source fires. Additionally, cable fire testing reports, including the recent CHRISTIFIRE phase 1 report [2], were reviewed to identify limiting data that could be used to improve the method outlined in NUREG/CR-6850 and more closely match the event experience.

2.1 EPRI Fire Events Database / Industry Experience

The existing EPRI FEDB (i.e., the same version used in the development of NUREG/CR-6850) was examined to look for incidents where the ignition source was “Cable fires caused by welding and cutting.” This search yielded 10 fire events where all but one were apparently very small fires with limited or no damage. The one notable fire had a suppression time of approximately 30 minutes, but no indication of the extent of the damage was provided in the FEDB[1].

An additional search of the FEDB was made identifying events where the Initiating Equipment was related to "cable." This search yielded 47 events although, as noted below, one of these appears to be a duplicate record[2]. Of these events, most self-ignited cable fires listed causes such as underrated cables, overloaded trays, short circuits, and cable bunching or pinching. The majority of these fires self-extinguished and damage was limited to the cable that initiated the fire.

The two earliest events (represented by records 2-4 in the FEDB) warrant further discussion of the details due their duration. Both fires involved a specific set of 480Vac power cables leading to pressurizer heaters inside containment at the San Onofre Nuclear Generating Station (SONGS) and they occurred approximately 6 weeks apart in 1968. These particular events were well known and well documented at the time and were the primary impetus for later revisions to the cable ampacity tables, cable ampacity analysis methods, and for the addition of the flame-spread test element to IEEE-383 (1974). The utility issued an extensive report on the incidents that included detailed event descriptions and root cause analysis[3]. Note that these events predate the NRC fire protection regulations by over a decade and, at the time, fire protection strategies were based on common industrial practices. In 1990, the NRC issued an instruction for providing a comprehensive inspection focused on electrical distribution systems at operating plants, entitled Electrical Distribution System Functional Inspection (EDSFI) [3]. The implementation of this process focused on identifying and correcting issues that would lead to this type of event.

Investigations showed that both fires resulted from excessive currents on a specific set of power cables. The incidents are summarized as follows:

- FEDB #2: On February 7, 1968 alarms were received in the MCR and a loud noise was heard in the plant at approximately 4:45AM. Responders immediately observed a fire in cables at a containment electrical penetration assembly head area. The fire was extinguished quickly. The full report indicates suppression within 2 minutes although the FEDB indicates a duration of 30 minutes. The fire occurred within the penetration head assembly and damaged all of the cables associated with that penetration but did not spread and did not cause damage to any other cables. The root cause analysis determined that the fire was

[1] Of the 10 events, 7 were determined to be potentially challenging according to the established criteria.
[2] The full utility report on these incidents describes two fires, one on February 7, 1968 and the second on March 12, 1968. The FEDB indicates a third incident on March 9, 1968, but this appears to be a duplicate record probably associated with an alternate source documenting the March 12 event. The description of the March 12 event indicates the fire occurred in the exact cable trays listed in the utility report of the March 12 event.
[3] "Report on Cable Failures – 1968," San Onofre Nuclear Generating Station Unit 1, Southern California Edison Company and San Diego Gas and Electric Company. Note that the publication status of this report is uncertain and the document appears to be an internal utility report provided to the NRC following the incident. A full copy of the report remains on file at SNL as a record dating from the early NRC fire protection research programs.

caused by cable overheating which was in turn caused by a lack of air circulation within a weather protection cowl at the head of the electrical penetration assembly.

- FEDB #3 and #4 (these two records refer to the same event): On March 12, 1968, smoke was seen coming from a 480V switchgear room. The detailed event timeline reports indications of electrical faults 5-10 minutes before smoke was seen. Plant personnel lacked the equipment needed to enter the smoke-filled room so firefighting support was requested from a nearby U.S. Marine Corp firefighting unit. The off-site firefighters arrived within approximately 20 minutes of detection but the pump on their fire truck failed to start, further delaying the initiation of suppression efforts. An alternate plant systems pump (an engine driven screen wash pump) was used to supply water and the fire was then extinguished within 4 minutes. Overall, the utility report indicates that the fire burned unchecked for at least 35 minutes and likely for closer to 45 minutes (versus the FEDB which indicates a total fire duration of 105 minutes). The fire damaged a substantial section of three stacked cable trays. The root cause analysis determined that the fire was caused by long term overheating and subsequent failure of the butyl insulation. The cables were rated for 32 amps but were carrying 45 amps.

The second incident was clearly the more severe of the two fires and, given the extent of fire damage, deserves some specific consideration. Several factors associated with this event make it unique and changes to industry practices make a repeat event unlikely.

1. The fire burned unchecked for an extended period (up to 45 minutes) because plant personnel were not equipped to fight such a fire and because the off-site fire brigade pumper failed to operate. Under current practices, the plant fire brigade is fully equipped and would be expected to initiate fire fighting for such a fire within 5-10 minutes at most. Redundant on-site fire pumps are also available at all sites.
2. The electrical protection scheme on the associated three-phase heater circuits used fusing such that only one phase cleared on initial faulting and the circuit continued to back-feed the faults through the heaters resulting in a continuous heating source over a substantial length within the tray. After the fire, these fuses were replaced with three-phase circuit breakers so that a similar situation would be prevented given a similar fault.
3. The plant had been operating with these cables in an overloaded condition for approximately one year prior to the fires and the cables likely suffered severe and premature aging degradation. Changes to ampacity limits as well as the EDSFI inspections prevent this situation in current applications.
4. The utility performed a cable tray thermal loading test to simulate the in-plant conditions prior to the fire and found cable temperatures as high as 158°C (316°F)[4] which is far in excess of the

[4] Note that the utility report actually cites the cable temperatures as 158°F (see page 5-7) and then states that this exceeds the cable rating of 90°C (a very typical cable rating level). However, 158°F equates to 70°C which would

90°C (176°F) cable insulation rating. This type of cable pre-heating will aggravate the subsequent fire behavior causing increased fire intensity and flame spread rates as demonstrated by testing in Germany[5]. Modern cable ampacity standards ensure that tray temperatures never exceed 90°C.

5. This event can be described as an "infant mortality" type fault that would certainly have been revealed if similar vulnerabilities existed at other members of the U.S. NPP fleet given their operating experience.

As a final note, the utility report specifically states that "The fire was of such a limited nature that there was no overheating to the grating and beams or the air intake located 38 inches above the trays." This is a further indication that the fire was likely mainly associated with smoldering combustion rather than open flaming. The fact that a relatively long section of tray was damaged (15 feet) can be attributed to the overloaded cables acting as a continuous line heating source along the length of the tray throughout the incident. It is likely there was smoldering combustion within the mass of cables in the most heavily loaded section of the trays and little other burning.

Overall, the March 1968 SONGS fire is an outlier relative to these type events. A repeat of this type of fire incident does not seem plausible given the many changes that resulted from these early fire events and the many changes to plant fire protection programs. Insights from these two SONGS cable fires led to significant reductions in cable ampacity limits for tray applications, restrictions on cable tray loading levels, and changes in common practice relative to circuit protection features. There have been no similar incidents at any U.S. Nuclear Power Plant (NPP). At most, such events have led to localized failures in a small number of cables within a single raceway. No event has led to sustained open flaming fires nor any damage to cables beyond the initially impacted raceway. More recent fire event data also support this conclusion. As a part of the NRC's audit of the recent EPRI FEDB update efforts, all of the newly identified events were reviewed by an NRC audit team. The review team paid particular attention to rare fire event types including various types of cable fires. The team did not encounter any events in the update set involving a significant self-ignited cable fire or hot-work related cable fire leading to failure of more than a small number of cables. This updated database will be evaluated further in greater detail when the updated EPRI FEDB is published.

Other than the SONGS type event, there have been several ventilation-limited fire events at international facilities which warrant additional consideration when analyzing self ignited cable fires. One such event is summarized as follows.

- On May 16, 2004 a cable fire occurred in a fire-resistant penetration carrying 6.6 kV electrical cables and other cables between the electrical building and the turbine hall. Other

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not exceed the cable temperature rating. Also, the document consistently reports temperatures in °C throughout with, apparently, this one exception. Overall, it appears clear that this one instance of °F is a typographical error and the measured temperature was actually 158°C.

[5] See Section 2.2 for a discussion of the cable pre-heating fire tests performed at the Braunschweig University for Technology in Germany.

> important safety-related cables were also routed through this penetration, including 380V power supply cables for line protection equipment and turbine bypass system actuators. The fire was caused by overheating of the 6.6 kV cables powering the pumps circulating water to the condenser. These cables were undersized with a rated power of 9 MW. In addition, the cable penetration concerned was closed at both ends allowing a build-up of heat causing an 'oven' effect and carbonization of the cables. The root cause was identified as the confinement of the cables in penetrations with two bulkheads as well as the sizing of the cables used to supply the pumps. The cumulative effect of these two conditions was the creation of a hot spot and an outbreak of fire at the opening to the penetration [4]

2.2 Fire Testing

A review of previous fire testing was conducted to identify information gained respective to ignition parameters for cable fires. Several test series were found to provide some indication of the minimum threshold parameters for ignition.

The first tests to consider are those performed by the utility in the wake of the 1968 SONGS fires that did reproduce some aspects of the fire behavior observed during the March fire in particular. The utility tests reproduced the actual plant conditions including both the electrical and physical loading conditions. The cables were energized and preheated before fire testing to simulate the in-plant conditions. The tests also simulated the phase-to-phase short circuit and allowed for the power back-feed situation to persist as it did in the actual fire. Under these conditions, the utility was able to produce flaming combustion. However, more recent testing in Germany (discussed below) is relevant to the interpretation of these results and the original SONGS fire.

Among the fire tests performed in the 1970's and 1980's at SNL and summarized in a 1989 document [5], two test series are of particular interest. Electrically Initiated Cable Fire tests, conducted in 1976, examined the potential for the development of self-ignited fire in qualified cables. It was found that currents in the range of 120-130 amperes were required to induce open flaming in the particular cables tested. These tests also reported that in full-scale testing, "the intense period of fire activity persisted for between 40 and 240 seconds after which rapid reduction to self-extinguishment was observed." None of these tests on qualified cables resulted in propagation of fire beyond the tray of fire origin. Because of these tests, the NUREG/CR-6850 methodology does not call for postulated self-ignited cable fires in qualified cabling.

In the 1977 testing at SNL focused on Cable Tray Exposure Fire testing, a minimum exposure time of 5 minutes to establish sustained combustion in a single cable tray was observed. A comparison of the fire tests for self-induced fires with the exposure fire tests yielded important insights:

> *Significant differences were also noted in the heat transfer processes observed for self-ignited and for exposure fire conditions. In all cases the flame temperature was roughly 1900^{o}F (1027^{o}C). However, the luminous flame zone for the electrically initiated fires was optically thin with an apparent emissivity*

on the order of 0.1 measured. This is quite low in comparison to typical values for larger fires, and implies a correspondingly lower intensity thermal radiation output from such fires. It was noted that the transfer of heat to immersed objects was convection dominated in the electrically initiated fires and radiation dominated in the larger exposure fires.

These tests, although performed on qualified cables, are relevant because hot work fires are considered for both types of cables. Hot work fires are caused by ignition sources such as small pieces of molten slag. A small quantity of molten slag will be hot, but based on the small mass; will have a much smaller heat capacity than a pilot fire with substantial fuel feeding it, as used in this testing.

In recent years (2005-2007) the Braunschweig University for Technology assessed the impact of cable preheating on fire behavior [6]. Tests were performed with the cables at room temperature at the time of ignition and with the cables pre-heated to either 200°C or 400°C prior to ignition. They observed significant increases in both the peak fire heat release rate and the rate of fire spread for the preheated cables at both levels. For example, they report that flame spread rates were as much as 3.5 times faster given cable pre-heating. As noted above, the SONGS cable tray was preheated to as much as 158°C based on the electrical loading conditions and as verified during the tests. This is a condition that would not be possible given modern ampacity standards. This testing provides further evidence that the 1968 SONGS fire was an outlier case that would not be expected to be repeated today.

NUREG/CR-4527 [7] reports fire tests in NPP control cabinets. The purpose of these cabinet fire tests was to characterize the development and effects of internally ignited cabinet fires as a function of several parameters believed to most influence the burning process. Tests ST1 and ST2 with peak heat release rates of 24 and 27 kW, respectively, involved exposing a cable bundle to a transient ignition source. The electrical cabinet in these two tests involved qualified cables and no ventilation. The report concluded that the ignition source was not intense enough to ignite and propagate a fire through the cable bundle. As mentioned above, this testing is relevant because hot work fires are postulated for both qualified and non-qualified cables.

NUREG/CR-7010, CHRISTIFIRE (Cable Heat Release, Ignition, and Spread in Tray Installations during FIRE) provides the results of small, intermediate and full-scale cable fire testing in horizontal trays. The intent of the experiments was to develop models for calculating heat release rates and flame spread behavior in cable fires. In this testing, the results of the cone calorimeter experiments where cables were exposed to 25 kW/m^2 indicated that ignition was achieved but in many cases without sustained burning[1]. The CHRISTIFIRE report goes on to assert that, “The cone calorimeter results suggest that the recommended ignition heat fluxes [in NUREG/CR-6850] might be too low to cause ignition and sustained burning of a group of electrical cables.” These results corroborate the early NRC/SNL test results cited above.

2.3 Example Using Existing Method in Appendix R

To illustrate the potential for overestimation given by the existing methodology in Appendix R, an example calculation was performed.

For this example, consider a stack of two cable trays, each 0.6 m (2 ft) wide, with unqualified cables. The postulated self-ignited cable fire is located in the lower tray and the target is in the top tray. According to the methodology in Appendix R of NUREG/CR–6850, the equation from Section R.3 should be used to calculate the initial intensity of the fire.

$$\dot{Q_{ct}} = 0.45 * \dot{q}_{bs} * A$$

Where

$\dot{Q_{ct}}$ is the heat release rate (HRR) from the cable tray (kW)
$\dot{q_{bs}}$ is the experimental bench scale HRR (kW/m^2) (from Table R-1)
A is the burning area of the tray (m^2)

The bench scale HRR values are given in Table R-1. For this example, the average value for the six PE/PVC based materials was chosen to represent the self-ignited cable fire case: 350 kW/m^2. The burning area, calculated as the square of the tray width, has a value of 0.4 m^2. Therefore:

$\dot{Q_{ct}} = 0.45 * 350\ {}^{kW}/_{m^2} * 0.4\ m^2 = 63\ kW$ with a corresponding $\dot{q_{ct}}$ = 158 kW/m^2

where $\dot{q_{ct}}$ is an equivalent *net* heat release rate per unit area comparable to the values reported in CHRISTIFIRE.

Using the NRC FDT^s fire modeling spreadsheets[6], the estimated flame height for this case is 0.53 m. This does not appear to match any of the actual fire events with the possible exception of the 1968 SONGS outlier event. A flame of 0.53 m would be sufficient to engulf 2-3 additional cable trays given typical tray spacing and such behavior would be notable when reporting an incident. Even in the case of the SONGS event, photos from the utility test show flames that were no more than a few inches tall (the actual fire event could not be observed directly due to smoke).

As a further investigation of this example, when the lowest bench scale value from Table R-1 (178 kW/m^2 for the XPE/XPE cables, a thermoset qualified cable) is used as a lower-bound value applicable to hot-work cable fires, the method yields:

[6] Heskestad flame height model as implemented in NUREG-1805 was used.

$\dot{Q_{ct}} = 0.45 * 178 \ {kW}/{m^2} * 0.4 \ m^2 = 32 \ kW$ with a corresponding $\dot{q_{ct}}$ = 80 kW/m^2.

Even this is a relatively large fire and the FDT[s] correlation yields an estimated flame height of 0.24 m.

For both the self-ignited cable fires and hot-work cable fires, the fire conditions as estimated above begin at time=0 (time of ignition) and the fire would then be assumed to grow and spread in accordance with the other modeling tools provided in NUREG/CR-6850 Appendix R. By comparison, the 75th percentile peak HRR value for an electrical cabinet fire where the fire is limited to one cable bundle is 69 kW which is not reached for 12 minutes (see NUREG/CR-6850 Table G-1). These cases are not self-consistent because the self-ignited and hot work-caused cable fires have no corresponding growth rate prescribed in NUREG/CR-6850.

2.4 Discussion

According to the values for generic screening criteria for the ignition and damage potential of electrical cable in Appendix H of NUREG/CR-6850, thermoplastic and thermoset cables are given radiant screening heating criteria of 6 kW/m^2 and 11 kW/m^2, respectively. The above example clearly exceeds these values even when the cable with the lowest HRR was chosen for the calculation. If the above value of 80kW/m^2 is used in the analysis, it would be evident that the cables in the higher tray would be exposed well above their ignition threshold and therefore the target would be affected. However, in actual NPP fire experience with more than 50 fires, only the March 1968 SONGS fire led to a self-sustained cable fire with damage beyond a single raceway. In all other cases, self-ignited cable fires did not propagate and develop into challenging fires. The SONGS fire, as discussed above, is considered an outlier although the presence of an under-ventilated condition could expose cabling to a similar overheating scenario. A recent international event in 2004 demonstrated this possibility. Under-ventilated conditions need to be evaluated on a plant-specific basis for all cable types.

To address this discrepancy between existing methodology and fire experience, a method is proposed whereby the cable raceways in a given compartment are evaluated one at a time to determine if significant values for the Core Damage Frequency (CDF) result based on the proportion of the fire frequency assigned. This process assumes that a self-ignited or hot work-caused cable fire does not propagate beyond the raceway of origin. In other words, a target located in the compartment would be affected only if it existed in the tray of fire origin. In essence, a tray containing multiple targets (cables) of interest to the PRA would have a higher resulting Conditional Core Damage Probability (CCDP) value and, based on the fire frequency allotted, would survive this screening process.

The benefit of this procedure is that effort is not wasted carrying fire scenarios through the analysis that in reality would not result from these low-intensity ignition sources. The details of this process are provided in the proposed revised Section R.1 text.

3 Proposed Text for Section R.1

Two types of cable fires are described in Task 6 as part of the frequency model: self-ignited cable fires and cable fires caused by welding and cutting. Self ignited cable fires should be postulated in rooms with unqualified cables only or a mix of qualified and unqualified cables.

These types of fires generally begin as relatively small and grow very slowly over some significant period of time. In most cases these fires do not generate enough heat to be self-sustaining and will self-extinguish prior to spreading beyond the ignition tray. In effect, this approach assumes that the zone of influence for these fires is equal to the tray of initiation only. This 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 compartment are estimated using the existing methods. For cable fires caused by welding and cutting, the transient weighting methods (see NUREG/CR-6850, Section 6.5.7.2[7]) should be used to estimate the compartment fire frequency for this ignition source. For self-ignited cable fires, a cable mass ratio can be calculated by dividing the initial cable mass on fire by the total mass of cable in the room. In most cases the initial cable mass on fire is one single raceway. This ratio can be used to calculate the compartment fire frequency for this ignition source ($\lambda_{IS,J}$).

To illustrate this calculation, consider an example compartment with four cable raceways. The dimensions of the raceways and respective cable fill are given in Table R-0.

Table R-0
Dimensions of Cable Raceways for Cable Mass Ratio Calculation

Raceway Number	Length [m]	Width [m]	Depth of Cable Fill [m]	Predominant Cable Type	Cable Density [R-7][8] [kg/m^3]
1	20	0.6	0.1	PVC	1380
2	15	0.6	0.2	XPE	1375
3	15	0.6	0.1	XPE	1375
4	15	0.6	0.2	PVC	1380

Using the dimensions of the cable raceways and depth of fill, the respective volumes for each raceway are calculated using :

Volume = Length x Width x Depth of Cable Fill

[7] Section 6.7.5 received significant edits during the Chapter 6 revision
[8] Reference R-7 refers to the Reference List at the end of Appendix R.

The density of the predominant cable type is then used to calculate the total cable mass of each raceway. If the predominant cable type is undetermined, the midpoint of the cable densities can be utilized (1378 kg/m^3).

Mass = Volume x Density

Table R-00 provides the results of these calculations as well as the cable mass ratio for each raceway

Table R-00

Cable Mass Ratio Example Results

Raceway Number	Mass of Cable (kg]	Cable Mass Ratio
1	1656	.21
2	2475	.32
3	1237.5	.16
4	2484	.32
Total Compartment Cable Mass	7852.5	

The resulting cable mass ratio is then used to pro-rate the compartment fire frequency for this ignition source ($\lambda_{IS,J}$).

Once these frequencies are calculated for a given compartment, perform a screening process as follows.

Step 1: Preliminary Analysis:

1. Calculate the CCDP values assuming the loss (failure) of one raceway at a time in the compartment (i.e., never more than one raceway is involved, and there is no sequential fire propagation from one raceway to another).

2. Repeat the calculation for every raceway located in the compartment that contains at least one fire PRA target cable and compile and sort the values in a table. (Note that some raceways may not contain fire PRA target cables.)

Step 2: First Screening Analysis:

1. Identify the tray with the largest CCDP value ($CCDP_{max, J}$) and estimate the CDF for the compartment as the product of the compartment fire frequency ($\lambda_{IS,J}$) and $CCPD_{max,J}$.

2. If this first screening level estimated CDF is low enough to meet PRA objectives, add this value to the compartment's total CDF and repeat this process for other compartments.

3. If the value is too large to meet PRA objective, conduct subsequent screenings as needed.

Subsequent Screenings (optional)

1. Calculate (partition) the fire frequency applicable to the previously identified raceway (e.g., $\lambda_{Tray1,J}$) used to arrive at the $CCDP_{max,J}$ above. For self-ignited cables, use the cable mass ratio of the target tray to the total cable mass in the compartment. For cable fires caused by welding and cutting, use a compartment area ratio based on the plan view area of the target tray to the total area of trays in the compartment (i.e., assume a welding fire is equally likely over the surface area of all cable trays present).

2. Re-estimate a CDF value for the previously identified tray (with the largest CCDP) as the product of the tray-specific fire frequency ($\lambda_{Tray1,J}$) and $CCDP_{max,J}$.

3. Identify the tray with the second largest CCDP value ($CCDP_{tray2,J}$), and calculate the CDF for the remainder of the compartment by assigning the remainder of the room frequency to that CCDP ($CDF = ((\lambda_{IS,J}-\lambda_{Tray1,J})xCCDP_{next,J}$).

4. The modified compartment CDF is then the sum of these two sub-cases.

5. Repeat the subsequent screening techniques as needed, working tray by tray down through the CCDP list, until PRA objectives are met or the analysis reaches the point of diminishing returns.

6. As an alternative, raceways may be grouped based on similar CCDP values and treated in groups rather than as individuals. That is, the CDF for a group of raceways 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).

7. It is recognized that some raceways will contain no fire PRA cable targets. For such raceways, if it can be confirmed that failure of cables in one or more raceways would not cause a plant transient then, consistent with other aspects of the general fire PRA methodology (e.g., qualitative screening[9]), those trays can be treated as a group having an effective CCDP value of 0.0 and, as such, non-contributors to fire-induced CDF.

This process 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 tray in CCDP ranking table. Note that since the entire cable tray is assumed

[9] During qualitative screening, the fire PRA is <u>not</u> required to assume that all fires will inevitably lead to a plant trip provided the fire-induced failures in a compartment would not cause a plant transient. The approach here is intended to match that practice with respect to individual cable raceways that do not contain fire PRA target cables and whose failure would not represent a trip initiator.

damaged upon initiation of the fire, no credit for suppression to prevent overall cable tray damage is allowed in this process.

For under-ventilated conditions, a separate analysis to address self ignited cable fires must be performed. In particular:

1. If the raceway is located in a configuration where the ventilation necessary to dissipate the normal heat load from the cables is inadequate, the under-ventilated condition must be addressed on a plant specific basis. For self ignited cable fires, both qualified and unqualified cables must be evaluated to assess if damage occurs beyond the initial tray.

2. This method of addressing self-ignited cable fires is not intended to overlook inadequately ventilated conditions.

References

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4. U.S. Nuclear Regulatory Commission. Office of Nuclear Reactor Regulation, Office of New Reactors, *NRC Information Notice 2010-02: Construction-Related Experience With Cables, Connectors, and Junction boxes,* January 28, 2010

5. *A Summary of Nuclear Power Plant Fire Safety Research at Sandia national Laboratories, 1975-1987* (NUREG/CR-5384, SAND89-1359), December 1989.

6. See, for example: Olaf Riese, "*Fire Behaviour of Cables with Insulation Materials Frequently Used in Nuclear Power Plants*," Structural Mechanics in Reactor Technology (SMiRT 19) 10th

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