

# **NRC INSPECTION MANUAL**

APHB

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INSPECTION MANUAL CHAPTER 0609 APPENDIX F ATTACHMENT 3

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GUIDANCE FOR IDENTIFYING CREDIBLE FIRE SCENARIOS

## GUIDANCE FOR DEVELOPING FIRE SCENARIOS

The purpose of Step 2.2 is to identify credible fire scenarios that may have to be considered in a Phase 2 evaluation, and to collect the information that is required to perform the analysis. Each fire scenario is uniquely defined by the ignition source (i.e., the fuel package that starts the fire) and a fire damage state or FDS to the targets (i.e., the extent of the damage from the fire). Some scenarios involve secondary combustibles. For example, FDS 2 can generally not be reached in fires that are initiated by a fixed or transient ignition source unless secondary combustibles are involved.

It is important to note that, since the objective of a Phase 2 analysis is to quantify the risk increase ( $\Delta$ CDF) due to the deficiencies that resulted in the finding, only scenarios that contribute to this risk increase need to be considered. Consequently, guidance for identifying the fire scenarios to be included in a Phase 2 analysis varies depending on the finding category.

- Findings in the “Fire Prevention and Administrative Controls” category typically only affect hot work or transient fires. Consequently, depending on the nature of the finding, only hot work or transient fire scenarios will need to be considered in the Phase 2 analysis.
- Findings in the “Fixed Fire Protection” category can result in a significant increase of the non-suppression probability (NSP), although they do not affect manual fire suppression involving use of portable extinguishers or hose stations. If a degraded water-based fire suppression system provides partial coverage of the area being evaluated; only ignition sources that are not covered by the suppression system need to be included in the Phase 2 analysis.
- Findings in the “Fire Water Supply” category may affect automatic as well as manual suppression, and are likely to have a risk impact in multiple areas. Findings in this category that are not screened to Green in Step 1.4.3 therefore usually require a Phase 3 analysis.
- The  $\Delta$ CDF calculation for findings in the “Fire Confinement Category” may involve scenarios in two areas that are separated by the degraded barrier. For example, if the barrier separates two compartments with redundant trains, either can be the exposing or the exposed compartment depending on where the ignition source is postulated. In this example the contribution from both areas needs to be included in the  $\Delta$ CDF estimate. In some cases only one of the two compartments needs to be considered as the exposing compartment. For example, for a finding that involves a degraded barrier between the turbine building and the main control room, the primary concern is likely to be the potential adverse effect of a fire in the turbine building on control room habitability.
- A finding in the “Manual Fire Fighting” category is likely to have little risk impact in areas that are protected by a fixed fire suppression system, and will result only in a slightly higher NSP. However, the impact can be more significant in areas that are not equipped with a fixed fire protection system, and a Phase 3 analysis may therefore be required if multiple areas are affected.
- The Phase 2 analysis of findings in the “Localized Cable or Component Protection” category is usually limited to scenarios that involve ignition sources in the immediate vicinity of the degraded protection and/or scenarios that result in the development of a damaging hot gas layer (HGL).
- Safe shutdown findings are related to degradations in operational aspects of post-fire safe shutdown such as manual actions, analysis of associated circuits, analysis of required circuits, spurious operation, alternate shutdown, fire response procedures, the

post-fire safe shutdown analysis, etc. The safe shutdown finding category is not intended to cover findings against physical protection of the designated safe shutdown path such as passive fire barriers, fire detection, and fire suppression. Findings against physical protection features are covered under other finding categories. The Phase 2 analysis of findings in the “Post-Fire Safe Shutdown” category is usually limited to scenarios that involve ignition sources in the immediate vicinity of components or locations requiring manual actions involved with the safe shutdown path.

- A finding in the “Main Control Room Fires” category will require an assessment of fire and damage propagation in the main control board (MCB) and/or an evaluation to quantify the probability for main control room (MCR) abandonment. Both are beyond the scope of a Phase 2 evaluation, and a Phase 3 analysis will therefore be needed.

## IGNITION SOURCES

Identification of credible fire scenarios usually starts with developing a list of relevant ignition sources in the area under investigation. Only ignition sources that have the potential of starting a fire that may increase the risk over the baseline risk (i.e., the risk for the area under evaluation assuming no deficiencies) need to be included. Since prior to performing a Phase 2 analysis it is generally not known if and how a fire will affect the risk, all ignition sources may need to be added to the list at this stage. However, often a subset of the ignition sources can be eliminated because none of the fires they start are affected by any of the deficiencies that resulted in the finding. For example, if the finding is a degraded water-based fire suppression system that provides partial coverage of the area being evaluated, only ignition sources that are not protected by the suppression system need to be included since fire scenarios that involve the remaining ignition sources are accounted for in the baseline risk. When the location of the targets of concern is known, which is generally the case for findings in the Localized Cable or Component Protection and the Post-Fire SSD categories, the list of ignition sources can often be substantially reduced since those that are not capable of damaging the targets, either directly or by igniting secondary combustibles, do not need to be considered.

Any ignition source that is retained on the list is assumed to start a fire with a given probability, which is based on plant fire event frequency statistics (see Attachment 4). If no fire ignition sources exist in the area under investigation, then no fire scenarios can be developed, except for transient fires. Note that a transient fire, if the only possibility, should always be postulated even if administrative/combustible controls seem to preclude this possibility. However, typically any of the following ignition sources are present:

- Fixed ignition sources: electrical cabinets, motors, and pumps
- Ignition sources that are susceptible to high energy arcing faults (HEAFs)
- Transient ignition sources: loose trash, trash in a container, etc.
- Combustible liquid fires: confined pool fires and unconfined spill fires
- Self-ignited cable fires
- Hot work fires
- Transformers
- Turbine/Generator set
- Hydrogen fires

Specific guidance for the information that needs to be collected for these ignition sources is provided below.

## Electrical Cabinets

Since it may not be possible to open electrical cabinets to examine the contents, for a Phase 2 analysis it is conservatively assumed that all electrical cabinets contain the default (maximum) fuel loading consisting of thermoplastic (TP) cables. The following information needs to be recorded for each electrical cabinet:

- Type: The heat release rate (HRR) of an electrical cabinet is based on the distributions reported in NUREG-2178, Vol. 1. The NUREG categorizes electrical cabinets into six different types based on function or physical size:
  - Switchgear and Load Centers: The term “switchgear” generally refers to medium voltage ( $>1000$  VAC) switching equipment. The term “load center” is commonly used to describe low voltage ( $\leq 1000$  VAC) switchgear.
  - Motor Control Centers (MCCs) and Battery Chargers: Although these two device types perform markedly different functions, the two are combined into one group for fire characterization based on similarities in size, fuel loading, and the energy available to potentially initiate a fire.
  - Power Inverters: This includes electrical cabinets whose primary purpose is to house a DC-to-AC power inverter, and is not intended to include other electrical enclosures that happen to house one or more small power inverters such as those that might service individual circuits or devices.
  - Small Electrical Enclosures: Includes the remaining electrical cabinets that have a volume of  $12 \text{ ft}^3$  or less.
  - Medium Electrical Enclosures: Includes the remaining electrical cabinets that have a volume greater than  $12 \text{ ft}^3$  and  $50 \text{ ft}^3$  or less.
  - Large Electrical Enclosures: Includes the remaining electrical cabinets that have a volume greater than  $50 \text{ ft}^3$ .
- Configuration (Closed or Open): Switchgear, load centers, MCCs, battery chargers, and power inverters are normally closed and opened only when being serviced. Other types of electrical enclosures may be closed or open. A “closed” configuration means that metal panels enclose all four sides and the top of the electrical enclosure. Enclosures that are not floor-based must also have a metal cover on the bottom. A closed electrical enclosure may have ventilation openings, even if they are present over essentially the full surface of a panel or door as long as the door is normally closed. A closed electrical enclosure may also have surface mounted components on one or more of the side panels. An “open” configuration means that one or more sides of the enclosure are effectively missing. For enclosures with a wire mesh, if half or more of a side is mesh the cabinet should be considered open. Some judgement may be needed in cases where a substantive portion of one side panel is comprised of a plastic cover that would be expected to melt in the early stages of a fire rendering a nominally closed enclosure open. As a general rule, if the plastic section represents one-half or more of the side panel or door surface, the enclosure should be treated as open.
- Location (Default, Wall, or Corner): The wall location is assumed for electrical cabinets that are at a distance of 2 ft. or less from a wall. The corner location applies to electrical cabinets that are at a distance of 2 ft. or less from the two intersecting walls of a corner.

Electrical cabinets of a particular type, configuration and location can be grouped together, provided they have the same potential for causing ignition or damage of a specified target or target set.

## Ignition Sources Susceptible to High Energy Arcing Faults (HEAFs)

Both switchgear and load centers (440V and above) are subject to a unique failure mode and, as a result, unique fire characteristics. In particular, these types of high energy electrical distribution and switching panels are subject to electrical arcing failures. This failure mode leads to the rapid release of electrical energy in the form of heat, vaporized copper, and mechanical force. Faults of this type are also commonly referred to as high energy, energetic, or explosive electrical equipment faults or fires.

The arcing or energetic fault scenario is in addition to the possibility of a general or thermal fire in these same components. That is, switchgear and load centers are subject to two types of fires, a general electrical cabinet fire and a secondary fire resulting from the arcing fault fire. The fire frequency, fire characteristics, and manual suppression curve are unique for each fire type. In dealing with postulated switchgear and load center fires, both fire types should be considered.

HEAFs can also be generated in bus bars or ducts. Bus ducts fall into one of the following four general categories:

- Non-segmented or continuous bus ducts: Bus bars associated with each power phase are comprised of a single length of metal bar connecting two end-devices. HEAFs in continuous bus ducts only occur at the termination points.
- Segmented bus ducts: Bus bars are made up of multiple sections bolted together at regular intervals. Segmented bus duct HEAFs can also occur at the transition points, i.e., the locations where the bus bar sections are bolted together.
- Cable ducts: Use a length of insulated electrical cable in lieu of metal bus bars. Cable duct HEAFs only occur at the termination points.
- Iso-phase bus ducts: Bus bars for each phase are separately enclosed in their own protective housing. Iso-phase bus duct HEAFs only occur at the termination points.

HEAF scenarios for a continuous bus or cable duct, and HEAF scenarios at the termination points of a segmented bus duct are treated as originating in the end device. Therefore, the risk contribution from these HEAF scenarios is already accounted for. However, HEAF scenarios originating at the transition points of segmented bus ducts or at the termination points of iso-phase bus ducts are not accounted for and need to be considered separately in the Phase 2 analysis. If a segmented bus duct is present in the area under evaluation the following information is needed for the analysis:

- Record the location of the transition points along the length of the segmented bus duct if they can be identified based on external visual inspection or by plant electrical construction drawings.
- If the transition points cannot be identified, partitioning of fire frequency to a specific fire scenario is based on apportioning of the fire frequency equally along the length of the bus duct. This requires the following:
  - Estimate the total length of segmented bus duct present in the plant.
  - Measure the length of duct for which identified targets in the area under investigation fall within the bus duct arc fault zone of influence (ZOI). If this length is less than 12 ft., a minimum length of 12 ft. should be assumed. The ZOI of a segmented bus duct HEAF is determined based on the following assumptions: (1) molten metal is ejected from the bottom below the fault point

and spreads downward as a right circular cone with an angle of 15 degrees until it has progressed 20 ft., at which point the metal drops vertically as a cylinder (zero degree angle); and (2) molten metal is also ejected outward as a 1.5-ft. radius sphere from the fault point (centered at cross-sectional bus duct center).

If a termination point of an iso-phase bus duct is present in the area under investigation, record its location. The recommended ZOI for iso-phase bus duct fires assumes damage to any component or cable that would normally be considered vulnerable to fire damage located within a sphere centered at the fault point and measuring 5 ft. in radius.

### Motors

All electric motors shall be counted, except for pump motors (included as part of the pump) and small motors (5 HP or less). Note the location of the motor if it is within 2 ft. from a wall, or within 2 ft. from the intersecting walls of a corner. Batteries, junction boxes, reactor protection system motor generator (RPS MG) sets, dry transformers, and ventilation subsystems are considered to have the same HRR characteristics as electric motors.

### Pumps

Include all electrical pumps with a motor greater than 5 HP. Note the location of the pump if it is within 2 ft. from a wall, or within 2 ft. from the intersecting walls of a corner. Diesel-driven pump fires are included as part of the liquid fuel fires discussed below.

### Transients

One fire ignition source scenario that is applicable to all areas of the plant is transient fuel fires (e.g., trash, refuse, temporary storage materials, etc.) Transients can be placed anywhere that is physically possible in the area under evaluation but should first be postulated near critical targets, including “pinch-points” where targets from two different safety divisions can be damaged by the same fire. Transients should also be postulated in locations where secondary combustibles could be ignited. The origin of a transient fire is placed 2 ft. above the floor at the center of the postulated location.

For specified transient fire scenario a weighting factor is applied to reflect the likelihood that a transient fire will occur in one specific location versus all the other plausible locations in the area under evaluation. The transient fire frequency for the fire area is multiplied by the weighting factor to estimate the fire scenario fire frequency. That is, the weighting factor reduces the transient fire frequency for the entire fire area to that for the specific fire scenario in the specific location. The weighting factor is estimated as follows:

- Determine where in the area under evaluation transient fuel combustibles might be either temporarily or permanently stored.
  - Exclude normal pathways, designated clear spaces (e.g., in front of electrical distribution panels), or areas that are not accessible.
  - Include locations that might not be intended for the storage of such materials, but might see temporary storage based on convenience (e.g., materials might be pushed under a cable tray to get them “out of the way”).
  - Estimate the total floor space where temporary or permanent storage of transient fuel material is considered plausible (the “plausible” floor area).

- The critical floor area for the specified scenario is a subset of the “plausible” floor area.
  - Identify the damage or ignition target for the scenario.
  - Estimate the total floor area where ignition or damage is possible (the “critical” floor area). For example, if the critical target is a cable tray, the critical floor area is equal to the floor area below the tray where it is physically possible to place a transient combustible, expanded by 1 ft. on either side of tray (to be conservative).
- The weighting factor is the “critical” floor area divided by the “plausible” floor area:  

$$WF_{\text{transients}} = (\text{critical floor area, in ft}^2) / (\text{plausible floor area, in ft}^2)$$
- In most cases, it is possible to choose one location to conservatively represent all transient fuel fires. The location is chosen to minimize the fire growth and damage time. However, if the fire area contains two or more unique target sets that are spatially separated, additional locations and additional transient fire scenarios may be analyzed. Each scenario should be assigned its own weighting factor using the above method. When summed, the weighting factor for all transient fire scenarios should not add to more than 1.0 (in most cases the sum will be less than 1.0).

In summary, the following information needs to be recorded for each transient fire scenario:

- Postulated location of the transient combustible
- Corresponding ignition or damage target
- Weighting factor

### Combustible Liquid Fires

Combustible liquid fires involve spills of the fuel or oil reservoir of diesel pumps, diesel generators, air compressors, oil-filled transformers, ventilation subsystems, boilers, etc. The following information needs to be recorded for each fuel or oil reservoir:

- Total quantity of fuel or oil.
- Type of the combustible liquid. Pre-calculated HRRs and ZOI tables and plots are provided in Attachments 5 and 8, respectively, for the following combustible liquids:
  - Diesel fuel and fuel oil
  - Lube oil and mineral oil
  - Silicone fluid
- When the combustible liquid spill is captured in a pan or a diked containment, record the total liquid surface area.

Two distinct oil spill fires may need to be considered. The first scenario assumes a spill of 100% of the amount of fuel or oil that can be spilled. The second scenario considers a 10% spill. A severity factor of 0.02 is assigned to the first scenario, and 0.98 is used for the second scenario. For confined liquid pool fires it is not necessary to evaluate the two scenarios separately if the containment is large enough to hold 100% of the amount of fuel or oil that can be spilled.

### Self-Ignited Cable Fires

The following guidelines are used to determine if self-ignited cable fire scenarios are plausible and should be included in the risk calculations.

- Determine if self-ignited cable fires are plausible.
  - Self-ignited cable fires are considered plausible only for thermoplastic or non-qualified cables per the IEEE-383 standard. Self-ignited cable fires are assumed to be implausible for Kerite and thermoset cables. If self-ignited cable fires are not plausible, they need not be considered in the Fire Protection SDP analysis (no self-ignited cable fire scenarios need to be developed).
  - This approach assumes proper current limiting provisions (fuses and/or breakers) are provided for all cables. If this assumption is not applicable, additional guidance should be sought from the Regional or Headquarters fire protection staff.
- Determine if self-ignited cable fires should be included in risk calculations.
  - The frequency of a self-ignited cable fire occurring in a specific location is low, even if such fires are plausible. In most fire areas, fire risk will be dominated by fires involving other fixed fire ignitions sources, in large part because such fires are simply far more frequent. Hence, a defensible estimate of fire risk change can often be calculated without explicitly analyzing the self-ignited cable fire scenarios.
  - Self-ignited cable fire scenarios should only be analyzed when there is a specific set of post-fire safe shutdown cable damage targets that is not threatened by any fixed fire ignition source. This could occur under the following conditions:
    - The fire area being analyzed contains no fixed ignition sources (e.g., a cable tunnel or cable spreading room with nothing but cables in it), or
    - None of the fixed ignition sources is close enough to the target cables to cause ignition/damage.
  - Include specific analysis of self-ignited cable fires if and only if one or more of the above conditions is met. If none of the above conditions are met, do not analyze self-ignited cable fire scenarios.

The procedure for characterization of self-ignited cable fires is as follows:

- Choose a critical ignition zone.
  - A self-ignited cable fire will begin in a specific location, the ignition point. Many ignition points are possible, and the importance of any given ignition point is case-specific. The importance of a given ignition point is driven by its proximity to thermal damage targets (other cables or components of risk importance). Locations where a fire might lead to critical damage (loss of a risk-important thermal damage target set) are referred to as critical ignition points.
  - In some cases, a fairly specific location may be the critical ignition point. For example, the critical thermal damage target set might be two cables located in separate cable trays that cross at a particular location. In this case, ignition points near the crossing point would likely be the most risk-significant.
  - Often, a combination of critical ignition points may form a critical zone:
    - If the location of risk-important damage targets is poorly characterized, it may be assumed that a fire in almost any location could lead to critical damage.
    - If the critical cables are all located in a specific cable tray, any ignition point that could threaten that tray, including an ignition within the target tray, is a potential critical ignition point.
  - In effect, the collection of critical ignition points becomes a critical ignition zone. This zone must be defined for the fire area being analyzed.

- Calculate the critical ignition zone weighting factor
  - A weighting factor is used to characterize the likelihood that the fire will start within the critical ignition zone as compared to all other possible locations. The weighting factor is based on the linear feet of cable tray within the critical ignition zone versus the total linear feet of cable trays in the area being evaluated.
  - $WF = (\text{linear feet of trays in critical ignition zone}) / (\text{total linear feet of trays in fire area})$
  - The Weighting Factor (WF) is applied as a multiplier for the fire area fire frequency for self-ignited cable fires.
- Fire characterization assumptions:
  - Following ignition, the subsequent fire spread among the exposed cable trays is treated using the general rules for fire spread within a stack of cable trays.
  - Once a cable tray has ignited, including the tray in which the fire is assumed to start, all cables in that tray are assumed to be fire damaged (no additional time delay). The damage sequence for trays above the ignition point is as follows:
    - First tray above the ignition point: 4 minutes after the start of the fire
    - Second tray above the ignition point: 3 minutes after ignition of the first tray
    - Third tray above the ignition point: 2 minutes after ignition of the second tray
    - Fourth tray above the ignition point: 1 minute after ignition of the third tray
    - Subsequent trays in the stack: 1 minute after ignition of next lower tray
  - The HRR of the stack of cable trays can be determined from the tables and plots in Figures C.01 and C.02 in Attachment 8. Since the cables are thermoplastic, the following information is needed to perform the Phase 2 analysis:
    - Tray width (1.5 or 3.0 ft.)
    - Number of trays in the stack above the ignition point

### Hot Work Fires

For hot work fires, it is assumed that the hot work leads to ignition of either transient combustibles, exposed cables, or insulation materials depending on the specific situation. Transient combustibles could include flammable materials used in conjunction with the hot work itself (e.g., plastic sheeting or non-fire retardant scaffold materials).

- If the hot work is assumed to ignite transients, treat the subsequent fire like any other transient fuel fire.
- If the hot work is assumed to ignite exposed cables, treat the subsequent fire like a self-ignited cable fire.
- If the hot work fire is assumed to ignite insulation materials, seek additional guidance from Regional or Headquarters fire protection staff.

A weighting factor may be applied to hot work fires as described below.

- Determine if there is a designated location or locations within the fire area where hot work activities are performed, or if a location can be identified where hot work will be undertaken in the vast majority of cases.
  - If such a location exists, then hot work fires should generally be postulated to occur in the area of this location (e.g., within reach of sparks from the hot work).

- If only one hot work fire scenario is developed, the weighting factor is 1.0 (in effect, no weighting factor is applied).
- If multiple hot work fire scenarios are developed, each scenario is assigned a corresponding fraction of the total fire frequency (if three scenarios are developed, each scenario uses a weighting factor of 1/3).
- If hot work activities appear equally likely in several locations, use an approach similar to that discussed for transient fires:
  - Identify the “plausible” hot work fire locations.
  - Identify “critical” locations for a hot work initiated fire.
  - Calculate a weighting factor based on the relative size of the floor space in the “critical” versus “plausible” locations.

### Transformer Fires

Guidance from either Regional or Headquarters fire protection staff should be sought in the treatment of transformer fires in the yard. In other areas of the plant dry transformers are treated as electrical motors, while fires involving oil-filled transformers are analyzed according to the guidance for evaluating confined or unconfined combustible liquids fires depending on whether the oil spill is contained or not, respectively.

### Severe Fires Involving the Main Turbine Generator Set

For inspections involving the turbine building, a need to address severe fires involving the main turbine generator set may arise. In this case, additional guidance will be needed to complete the Phase 2 analysis. Guidance from either Regional or Headquarters fire protection staff should be sought in the treatment of these fires.

### Hydrogen Fires

Hydrogen fires may occur as the result of leakage from hydrogen tanks, hydrogen piping, and/or near a bearing/seal surface that contains hydrogen within process equipment (e.g., the turbine generator set or hydrogen recombiners).

If for a given fire area, hydrogen fires might be a significant factor in the risk quantification, additional guidance will be needed to complete the Phase 2 analysis. Guidance from either Regional or Headquarters fire protection staff should be sought in the treatment of these fires.

## FIRE DAMAGE STATES

### FDS 1

Develop a list of ignition and damage targets within the ZOI of the ignition source. Since the vertical ZOI is not known at this stage, initially include all targets between the top of the ignition source and the ceiling. Use the following table to determine the radial ZOI of fixed and transient ignition sources. The radial ZOI of combustible liquid fires can be determined from Figures A.07-A.09 and Figures A.13-A.15 in Attachment 8 for confined and unconfined combustible liquid fires respectively. The following information is needed for each target:

- Vertical distance of the target from the top of the ignition source, or radial distance between the target and the edge of the ignition source

| Table A3.1 – Radial ZOI for Fixed and Transient Ignition Sources (ft.) |          |          |                       |
|------------------------------------------------------------------------|----------|----------|-----------------------|
| Ignition Source                                                        | TS Cable | TP Cable | Sensitive Electronics |
| Small Electrical Enclosures                                            | 1.0      | 1.4      | 2.0                   |
| MCCs & Battery Chargers                                                | 1.7      | 2.4      | 3.5                   |
| Switchgear & Load Centers                                              | 2.0      | 2.8      | 3.9                   |
| Power Inverters                                                        | 2.1      | 3.0      | 4.3                   |
| Closed Medium Enclosures                                               | 2.1      | 3.0      | 4.3                   |
| Open Medium Enclosures                                                 | 2.7      | 3.8      | 5.5                   |
| Closed Large Enclosures                                                | 3.0      | 4.2      | 6.1                   |
| Open Large Enclosures                                                  | 4.7      | 6.7      | 9.6                   |
| Motors                                                                 | 1.2      | 1.8      | 2.5                   |
| Electrical Pumps                                                       | 2.2      | 3.1      | 4.4                   |
| Transients                                                             | 2.7      | 3.8      | 5.4                   |

- Target type: Sensitive electronics; thermoplastic, Kerite, or thermoset cable
- For cable targets:
  - Is the cable protected with a rated barrier system?
  - Is the cable protected with a rated fire wrap?
  - Is the cable in a tray with a solid bottom? If so, is the cable tray enclosed or is the top covered with ceramic fiber (Kaowool) blanket?
  - Is the cable located in a conduit?
- For sensitive electronics
  - Are the sensitive electronics exposed?
  - Are the sensitive electronics inside an enclosure, but mounted directly on the surface of the enclosure where it would be directly exposed to the convective or radiative energy of the exposing fire?
  - Are the sensitive electronics inside an enclosure that is provided with louvers or ventilation openings that allow for the entry of hot gases generated by the exposing fire?

## FDS 2

The HRR of fixed ignition sources, transient combustibles, and small oil fires is generally insufficient to create damaging HGL conditions in the area under evaluation. For these scenarios the HRR contribution from secondary combustibles is needed to reach FDS 2. The combined HRR profile for various ignition source/cable tray configurations can be determined from the pertinent tables and plots in Attachment 8, set C. The total HRR of combustible liquid fires in combination with fires in vertical stacks of horizontal cable trays can be determined by summing the HRR of the combustible liquid fire from Attachment 5 and the HRR of the cable trays from Figures C.01 or C.02 in Attachment 8.

The tables/plots in set C in Attachment 8 assume that following ignition of the first cable tray above the ignition source, the fire spreads among the exposed cable trays following the general rules for fire spread within a stack of cable trays. Once a cable tray has ignited, all cables in that tray are assumed to be fire damaged with no additional time delay. Assuming that the first cable tray in a stack of horizontal cable trays is within the zone of influence of a given fire ignition source, the damage times of targets in the trays within the stack are as follows:

- Damage time for targets in the first tray is determined from the vertical ZOI tables and plots in set F in Attachment 8.
- Targets in the second tray are damaged 4 minutes after damage to the first tray.
- Targets in the third tray are damaged 3 minutes after damage to the second tray.
- Targets in the fourth tray are damaged 2 minutes after damage to the third tray.
- Targets in the fifth tray are damaged 1 minute after damage to the fourth tray.
- Targets in the sixth and any subsequent trays are damaged 1 minute after damage to the tray immediately below.

The following information is needed to determine the fire propagation in vertical stacks of horizontal cable trays:

- Type of cables in the trays: Thermoplastic or thermoset. Mixed trays are assumed to contain thermoplastic cables if 95% or less of the tray contents are thermoset.
- Tray width (1.5 or 3.0 ft.)
- Number of trays in the stack
- Vertical distance of the bottom tray above the ignition source
- Location of damage targets in the trays
- Cable tray protection:
  - Is the cable tray protected with a rated barrier system?
  - Is the cable tray protected with a rated fire wrap?
  - Are the cables in a tray with a solid bottom? If so, is the cable tray enclosed or is the top covered with ceramic fiber (Kaowool) blanket?

To determine the HRR of vertical cable trays the following information is needed:

- Type of cables in the trays: Thermoplastic or thermoset.
- Tray width and height
- Information to determine how and when the tray will ignite, e.g., radial distance to the nearest most intense ignition source.
- Cable tray protection:
  - Is the cable tray protected with a rated barrier system?
  - Is the cable tray protected with a rated fire wrap?
  - Are the cables in a tray with a solid cover? If so, is the cable tray enclosed?
  - Are the cables covered with ceramic fiber (Kaowool) blanket?

Guidance from either Regional or Headquarters fire protection staff should be sought in the treatment of fires that involve non-cable secondary combustibles such as combustible insulation.

Table/plot set B in Attachment 8 can be used to determine if and when the combined HRR of the ignition source and secondary combustibles is sufficient to reach a damaging HGL condition. The following information is needed to use the tables and plots in this set:

- Type of cables in the compartment under evaluation: Thermoset cables, thermoplastic cables, and/or sensitive electronics. In some cases multiple FDS2 analyses are performed if different types of targets are present.

- Floor area and ceiling height of the compartment being evaluated. If the ceiling height varies throughout the compartment, use the lowest ceiling height for the entire compartment.

### FDS 3

The approach for evaluating FDS3 scenarios is similar to that used for FDS 2 scenarios, except that the two compartments on both sides of the degraded barrier are combined into one. The same information is needed as for FDS 2 scenarios, but for both compartments.

### Additional Information Needed to Perform a Detection and Suppression Analysis

The following information is needed to perform a detection and suppression analysis:

- Vertical distance between the top of the ignition source and the ceiling, and radial distance between the nearest detector and the ignition source. For cross-zone detection the radial distances from the ignition source to the nearest detectors in two zones are needed.
- Roving fire watch recurrence schedule
- For water-based suppression system, distance from the ignition source to the nearest non-degraded head
- Discharge delay and transport times for gaseous suppression systems, deluge systems, pre-action sprinklers, or dry-pipe water systems.

# ATTACHMENT 1

## Revision History for IMC 0609 Appendix F Attachment 3

| Commitment Tracking Number | Accession Number<br>Issue Date<br>Change Notice | Description of Change                                                                                                                                                                                                                                                                                                                            | Description of Training Required and Completion Date | Comment Resolution and Feedback Form Accession Number (Pre-Decisional, Non-Public) |
|----------------------------|-------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------------|
|                            | 05/28/2004<br>CN 04-016                         | IMC 0609, App F, Att 3 "Guidance for Identifying Fire Growth and Damage Scenarios," is added to provide fire scenario identification and ignition source screening including guidance for identifying fire growth and fire damage scenarios involving raceway fire barriers, spreading fires, cable tray configurations and non-spreading fires. |                                                      |                                                                                    |
|                            | 02/28/2005<br>CN 05-007                         | IMC 0609, App F, Att 3 "Guidance for Identifying Fire Growth and Damage Scenarios," is revised to correct the references to proper attachment - last sentence on page F3-6.                                                                                                                                                                      |                                                      |                                                                                    |
|                            | ML17089A420<br>DRAFT<br>CN 17-XXX               | Major revision to reflect changes to the Phase 2 process and to include guidance for the impact of the finding category on fire scenario development, identifying ignition sources, and identifying targets and secondary combustibles by fire damage state.<br><br>CA Note sent 7/18/17 for information only, ML17191A681.                      | November 2017                                        | ML17093A181                                                                        |