

NRC INSPECTION MANUAL

APOB

INSPECTION MANUAL CHAPTER 0609 APPENDIX F ATTACHMENT 3

GUIDANCE FOR IDENTIFYING CREDIBLE FIRE SCENARIOS

Effective Date: January 1, 2025

0609F.3-01 PURPOSE

The purpose of Step 2.2 of the Fire Protection Significance Determination Process (SDP), IMC 0609 Appendix F, 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 (FDS) relative 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. This attachment provides additional information to assist the user in performing Step 2.2 of the Fire Protection SDP.

0609F.3-02 GUIDANCE FOR IDENTIFYING CREDIBLE FIRE SCENARIOS

It is important to note that, since the objective of a Phase 2 analysis is to quantify the risk increase (i.e., change in core damage frequency, ΔCDF) 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 changes to the fire ignition frequencies (FIFs) for hot work or transient fire scenarios will need to be considered in the Phase 2 analysis (Step 2.4).
- 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. Therefore, changes may be required to the detection and suppression analysis (Step 2.7). 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 may require a Phase 3 analysis.
- Findings in the Fire Confinement Category will impact the identification of damage states that need to be considered (Step 2.2), and the fire damage time analysis for FDS3 fire scenarios (Step 2.7.1). The ΔCDF 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 ΔCDF 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 for 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). Therefore, findings in the Localized Cable or Component Protection Category may result in changes to the fire damage time analysis for FDS1 and FDS2 scenarios (Step 2.7.1).
- Post-Fire safe shutdown (SSD) findings are related to degradations in operational aspects of post-fire SSD such as manual actions, analysis of associated circuits, analysis of required circuits, spurious operation, alternate shutdown, fire response procedures, the post-fire SSD analysis, etc. The SSD finding category is not intended to cover findings against physical protection of the designated SSD 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 SSD 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 (MCR) Fires Category may require an assessment of fire and damage propagation in the main control board and/or an evaluation to quantify the probability for MCR abandonment. Both are generally beyond the scope of a Phase 2 evaluation, and a Phase 3 analysis may be needed.

0609F.3-03 GUIDANCE FOR IDENTIFYING AND CHARACTERIZING 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 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. The following ignition sources should be considered:

- Fixed ignition sources: electrical enclosures, motors, and dry transformers
- Ignition sources that are susceptible to high energy arcing faults (HEAFs)

- Transient ignition sources: cardboard box with paper or polystyrene packing material, plastic tarp, trash in a metal or plastic container, etc.
- Combustible liquid fires: confined pool fires and unconfined spill fires
- Self-ignited cable fires
- Hot work fires
- Turbine/Generator set
- Hydrogen fires

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

03.01 Electrical Enclosures

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

- Type: The heat release rate (HRR) of an electrical enclosure is based on the distributions reported in NUREG-2178, Vol. 1. The NUREG categorizes electrical enclosures into six different types based on function or physical size:
 - Group 1 Electrical Enclosures (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 (≤1000 VAC) switchgear.
 - Group 2 Electrical Enclosures (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.
 - Group 3 Electrical Enclosures (Power Inverters): This includes electrical enclosures 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.
 - Group 4a Large Electrical Enclosures: Includes the remaining electrical enclosures that have a volume greater than 50 ft³.
 - Group 4b Medium Electrical Enclosures: Includes the remaining electrical enclosures that have a volume greater than 12 ft³ and 50 ft³ or less.
 - Group 4c Small Electrical Enclosures: Includes the remaining electrical enclosures that have a volume of 12 ft³ or less.
- 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. The integrity of the door opening during maintenance activities or plant modifications can also impact the configuration classification. If door latches or

closure mechanisms are intentionally defeated or bypassed the door should be functionally considered open. For enclosures with a wire mesh, if half or more of a side is mesh the enclosure 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 (Free-Burn/Open or Corner): The corner location applies to electrical enclosures that are at a distance of 2 ft. or less from the two intersecting walls of a corner. The free-burn or open location applies to enclosures that are more than 2 ft. away from either of the intersecting walls of a corner.

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

03.02 Ignition Sources Susceptible to 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 enclosure fire and a secondary fire resulting from an arcing fault. 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:

- 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 in indoor locations generally only occur at the termination points. If the bus duct itself is vented or if there are points along the bus duct where foreign material intrusion or water intrusion can occur, then a new scenario location is postulated to account for operating experience. For outdoor locations with features that may allow degradation of the bus bar insulation (e.g., vents, hatches, and wall penetrations), fire PRA targets near these features should be captured and included with scenarios structured around the nearest transition points or alternatively considered as transition points.
- Non-segregated bus ducts: Bus bars are made up of multiple sections bolted together at regular intervals. Non-segregated bus duct HEAFs can also occur at the transition points, i.e., the locations where the bus bar sections are bolted together. The previous version of the Fire Protection SDP refers to non-segregated bus ducts as segmented bus ducts.

- 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 **non-segregated** bus ducts 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 **non-segregated** 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 **non-segregated** 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 **non-segregated** 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 **non-segregated** 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.

Guidance for determining the frequencies and ZOIs for switchgear, load centers, **non-segregated** bus ducts and iso-phase bus ducts based on the recommendations in NUREG-2262 is provided in the following four subsections. The schematic of the HEAF zones for a generic nuclear power plant electrical distribution system from NUREG-2262 is shown in Figure A3.1 below.

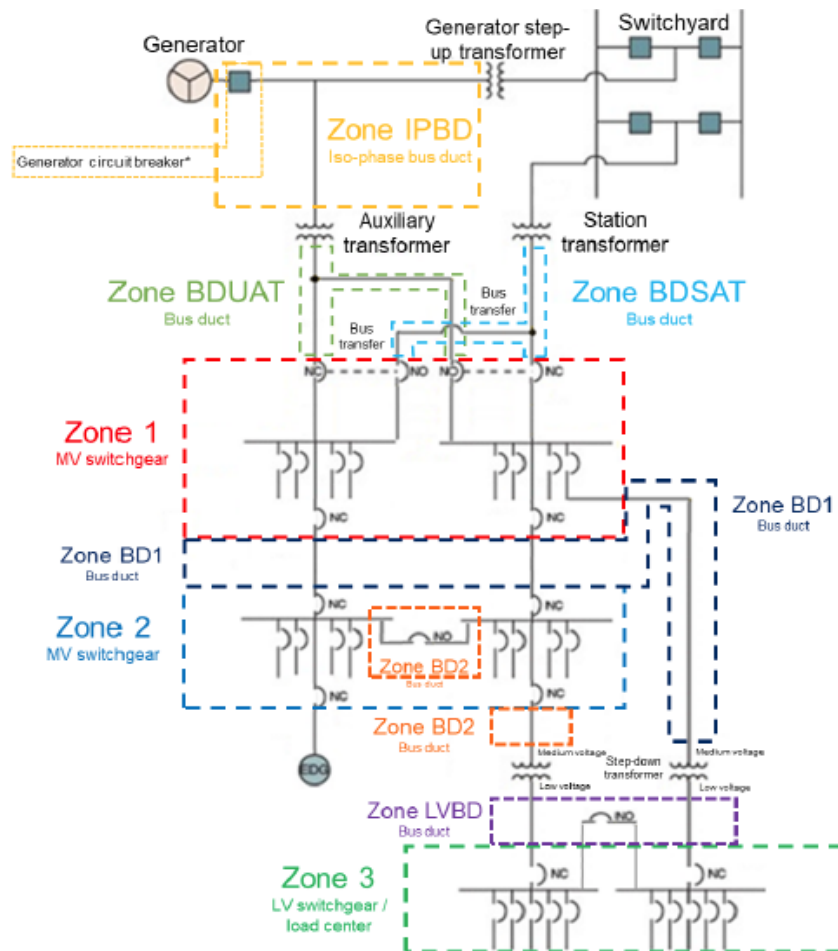


Figure A3.1 HEAF Zones for a Generic Nuclear Power Plant Electrical Distribution System (from NUREG-2262)

Frequency and ZOI for Switchgear HEAFs

The frequency of switchgear HEAFs depends on the location of the switchgear bank in the plant's electrical distribution system. Switchgear are located in HEAF fault zone 1 or HEAF fault zone 2. Switchgear in HEAF fault zone 1 are fed either by the unit auxiliary transformer (UAT) or by the station transformer (SAT). Switchgear in HEAF fault zone 2 are fed by switchgear in HEAF fault zone 1. The plant-wide fire ignition frequency (FIF) for switchgear (bin 16.b) is equal to $1.98\text{E-}03$, 86 percent of which is distributed between the switchgear in zone 1 and the remaining 14 percent is distributed between the switchgear in zone 2. To determine the per-unit fire ignition frequency for switchgear located in fault zone 1, divide the switchgear FIF for zone 1 ($0.86 \times 1.98\text{E-}03 = 1.703\text{E-}03$) by the switchgear count for zone 1 (for HEAF scenarios, switchgear are no longer counted by vertical section and each bank of switchgear is counted as one unit). To determine the per-unit fire ignition frequency for switchgear located in zone 2, divide the switchgear FIF for zone 2 ($0.14 \times 1.98\text{E-}03 = 2.77\text{E-}04$) by the switchgear count for zone 2.

NUREG-2262 provides screening ZOIs for switchgear HEAFs as a function of SAT or UAT fault clearing time and target fragility. According to NRC Research Information Letter (RIL) 2022-01, the target fragility for thermoplastic and thermoset cable targets is equal to 15 MJ/m^2 and 30 MJ/m^2 , respectively. If the transformer fault clearing times cannot be determined, the analyst

can use the most conservative vertical and radial ZOI values of 4.5 ft. for thermoplastic cable targets, and 3.5 ft. for thermoset cable targets. If the power transformer fault clearing time is available, refined ZOI values can be obtained from Table 10-3 in NUREG-2262 for switchgear HEAFs in zone 1 and from Table 10-4 for switchgear HEAFs in zone 2.

For HEAFs in switchgear (MV Zone 1 and 2), fire spread to switchgear vertical sections that are adjacent to where the HEAF initiated is postulated due to the potential for the arc to breach the shared boundary. A breach in the shared boundary could allow the HEAF and ensuing fire to expose the combustible contents of an adjacent section to an energy flux high enough to sustain ignition. For a more detailed description of fire spread to adjacent switchgear sections see NUREG-2262 section 6.5.1.

Frequency and ZOI for Load Center HEAFs

HEAFs in load centers are in HEAF fault zone 3. Load center HEAFs are only postulated at the supply circuit breakers. To determine the per-unit FIF, divide the plant-wide frequency for load center HEAFs (bin 16.a), which is equal to 5.32E-04, by the total count of supply circuit breakers. Table A3.1, which is based on Table 10-2 in NUREG-2262, gives screening ZOIs for load center HEAFs based on supply circuit breaker location and target fragility.

Table A3.1 – Screening ZOIs for Load Center HEAFs			
Circuit Breaker Location and Target Fragility	Back and Front	Side (ft.)	Top (ft.)
End location, upper elevation: 15 MJ/m ² (TP)	None	2.5	2
End location, upper elevation: 30 MJ/m ² (TS)	None	1.5	1
End location, lower elevation: 15 MJ/m ² (TP)	None	2.5	None
End location, lower elevation: 30 MJ/m ² (TS)	None	1.5	None
Interior, upper elevation: 15 MJ/m ² (TP)	None	None	2
Interior, upper elevation: 30 MJ/m ² (TS)	None	None	1
Interior, lower elevation: 15 MJ/m ² (TP)	None	None	None
Interior, lower elevation: 30 MJ/m ² (TS)	None	None	None

Frequency and ZOI for Non-segregated Bus Bar HEAFs

HEAFs in non-segregated bus ducts connected to the auxiliary power transformers are in HEAF zones BDUAT (bus duct off the UAT) and BDSAT (bus duct off the SAT), as shown in Figure A3.1. HEAFs in non-segregated bus ducts between zone 1 and zone 2, and between zone 1 and the step down transformer to zone 3 are in HEAF zone BD1. HEAFs in non-segregated bus ducts inside zone 2, and between zone 2 and the step down transformer to zone 3 are in HEAF zone BD2. Finally, HEAFs in non-segregated bus ducts between the step down transformers and zone 3 are in HEAF zone LVBD.

The counting guidance for non-segregated bus ducts in NUREG-2262 is consistent with the guidance from NUREG/CR-6850, Supplement 1 described earlier, except that for bus ducts with known transition points, analysts should also look for targets in locations with the potential for a HEAF to occur, such as ventilation openings and mechanical hatches on outdoor non-segregated bus ducts, and external wall penetrations (e.g., yard-to-turbine-building penetration), and ensure they are captured by scenarios developed around the counted transition points or are treated as transition points with scenarios developed at these locations.

The plant-wide FIF for bus duct HEAFs in zones BDUAT and BDSAT (bin 16.1-1) is equal to 2.61E-03. The FIF for bus duct HEAFs in zones BD1, BD2 and LVBD is equal to 8.98E-04.

The ZOI for all non-segregated bus duct HEAFs depends on the enclosure material of the initiating bus duct (either steel or aluminum) and on the fragility of the target (15 MJ/m² for thermoplastic cable targets and 30 MJ/m² for thermoset cable targets). In addition, the ZOI for non-segregated bus duct HEAFs in zones BDSAT, BD1, BD2 and BDLV also depends on the power transformer fault clearing time. If the transformer fault clearing times cannot be determined, the analyst can use the most conservative vertical and radial ZOI values in Table A3.2. If the power transformer fault clearing time can be obtained, refined ZOI values can be obtained from Table 10-10 in NUREG-2262 for bus duct HEAFs in fault zone BDSAT and from Table 10-12 for bus duct HEAFs in fault zones BD1, BD2 and BDLV.

Table A3.2 – Screening ZOIs for Non-segregated Bus HEAFs (in ft.)				
Bus Duct HEAF Fault Zone	Steel Encl. 15 MJ/m ² Target	Steel Encl. 30 MJ/m ² Target	Aluminum Encl. 15 MJ/m ² Target	Aluminum Encl. 30 MJ/m ² Target
BDUAT	2.5	1.5	3.0	2.0
BDSAT	3.0	2.0	3.5	2.0
BD1–UAT*	4.5	3.0	5.0	3.0
BD1–SAT**	3.0	2.0	3.5	2.0
BD2	1.0	0.5	1.5	1.0
BDLV	1.0	0.5	1.5	1.0

* Normally powered by UAT

** Normally powered by SAT

Frequency and ZOI for Iso-Phase Bus Bar HEAFs

The FIF for iso-phase bus bar HEAFs (bin 16.1-2) is 1.01E-03. There generally should be one iso-phase bus per plant. If there is more than one iso-phase bus, count the number of iso-phase buses and use that to calculate the per ignition source unit FIF.

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.

03.03 Motors

Electric motors are grouped into three classes based on size: classification group A (>5-30 HP), classification group B (>30-100 HP), and classification group C (>100 HP). Each classification group has different HRR characteristics. All electric motors shall be counted, except for small motors 5 HP or less. Note the location of the motor if it is within 2 ft. from the two intersecting walls of a corner. Batteries are considered to have the same HRR characteristics as Class B motors. Junction boxes are considered to have the same HRR characteristics as Class A motors. The HRR characteristics of electric pumps, reactor protection system motor generator (RPS MG) sets, and ventilation subsystems are based on the size of the electric motor that powers the pump or system.

03.04 Pumps

Electrical pumps are included as part of the electric motor fire discussion above. Diesel-driven pump fires are included as part of the liquid fuel fires discussed below.

03.05 Dry Transformers

Dry transformers are grouped into three classes based on power rating: classification group A (>45-75 kVA), classification group B (>75-750 kVA), and classification group C (>750 kVA). Each classification group has different HRR characteristics. All dry transformers shall be counted, except for small dry transformers 45 kVA or less. Note the location of the dry transformer if it is within 2 ft. from the two intersecting walls of a corner.

03.06 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). However, transient fuel fires in transient combustible control locations (TCCL) are assumed to have a lower HRR compared to the generic HRR of transients in other locations of the plant. 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 0.5 ft. above the floor at the center of the postulated location.

For each specified transient fire scenario an adjustment 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 FIF for the fire area is multiplied by the adjustment factor to estimate the fire scenario FIF. That is, the adjustment factor reduces the transient FIF for the entire fire area to that for the specific fire scenario in the specific location. The adjustment 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 **critical area adjustment factor (AF)** is the “critical” floor area divided by the “plausible” floor area: $AF_{transients} = (\text{critical floor area, in ft}^2) / (\text{plausible floor area, in ft}^2)$
- 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 **AF** using the above method. When summed, the **AF** for all transient fire scenarios should not add to more than 1.0 (in most cases the sum will be less than 1.0).

If a combustible control system exists with frequent surveillance patrols (at least once per shift) and a review of surveillance reports show no discovery of improperly stored combustibles during the exposure period, the low likelihood rating FIF for transient fires from Table A4.1 in Attachment 4 and the TCCL HRR profile discussed in Attachment 5 may be used in the analysis of the transient fire scenario.

Finally, an adjustment to the FIF for transient fires is made if the inspection findings are associated with the combustible controls program. In this case the FIF is increased as follows:

- For a fire area nominally ranked as a low or medium likelihood area for transient fires, the likelihood rating will be raised by one level of likelihood (i.e., a low likelihood area becomes a moderate likelihood area, and a moderate likelihood area becomes a high area) and the FIF is adjusted according to the revised likelihood fire frequency value.
- For a fire area already ranked as a high likelihood area for transient fires, the high likelihood transient fire frequency is multiplied by a factor of 3.

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
- **Adjustments to the FIF**

03.07 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 **should** be considered. The first scenario assumes a spill of 100 **percent** of the amount of fuel or oil that can be spilled. The second scenario considers a 10 **percent** 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 percent of the amount of fuel or oil that can be spilled.

03.08 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 not plausible for Kerite and thermoset cables. If self-ignited cable fires are not plausible, they should not be considered in the Fire Protection SDP analysis (no self-ignited cable fire scenarios need to be developed).
 - Eliminating the plausibility of self-ignited cable fires for Kerite and thermoset cables assumes proper current limiting provisions (fuses and/or breakers) are provided for all such cables. If this assumption is not applicable, additional guidance should be sought from Regional or Headquarters fire protection staff.
- Determine if self-ignited cable fires should be included in risk calculations.
 - Damage from a self-ignited cable fire is limited to the tray in which the fire begins. Under normal conditions, damage from a self-ignited cable fire is considered an FDS0 scenario and is not modeled in the Fire Protection SDP. Self-ignited cable fires should only be evaluated for abnormal plant conditions where cables are routed in the wrong cable tray or where the adequate separation of trains has not been established for cable trays.
 - The frequency of a self-ignited cable fire occurring is low. In most fire areas, fire risk will be dominated by fires involving other fixed or transient fire ignition sources because such fires are more frequent and present the possibility for more extensive fire damage. Therefore, a defensible estimate of fire risk change can usually be calculated without explicitly analyzing the self-ignited cable fire scenarios.
 - Self-ignited cable fire scenarios should only be analyzed when there are specific post-fire SSD cable damage targets that are not threatened by any other fixed or transient fire ignition source. This could occur under the following conditions:
 - The fire area being analyzed contains no fixed or transient ignition sources (e.g., a cable tunnel or cable spreading room with nothing but cables in it), or
 - None of the fixed or transient ignition sources is close enough to the target cables to cause ignition/damage.
 - If none of the above conditions are met, do not analyze self-ignited cable fire scenarios. If self-ignited cable fires need to be analyzed, seek additional guidance from Regional or Headquarters fire protection staff.

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

- Damage from a self-ignited cable fire is limited to the tray in which the fire begins.
- Although a self-ignited cable fire will begin in a specific location, the location of the ignition point is not important because the entire tray is assumed to be damaged

instantaneously upon ignition. The entire cable tray is assumed to be damaged since the analyst cannot predict the specific location in the tray at which the fire will begin. Since total tray damage is assumed instantaneously, suppression efforts do not reduce the likelihood of total tray damage.

- FAQ 13-0005 Revision 5 (ADAMS ML13319B181) specifies the technique to analyze the risk of self-ignited cable fires.
- Tray-specific frequencies for self-ignited cable fires are determined using the ratio of the cable volume of the tray in question to the total cable volume in the physical analysis unit. The CDF of a cable tray for self-ignited cable fires is (1) this ratio times (2) the physical analysis unit frequency for self-ignited cable trays times (3) the CCDP of the cable tray.
- For findings that require the contribution of many cable trays in the physical analysis unit, the graduated screening analysis in FAQ 13-0005 is also appropriate for the risk of self-ignited cable fires and is more efficient for many trays. Only those trays that figure into the quantification of the finding should have the CCDP determined and be addressed in the screening analysis. A graduated screening analysis will lead to a more conservative result than by only evaluating tray-specific frequencies as above.

03.09 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.

An AF may be applied to hot work fires to reflect the likelihood that a hot work fire will occur in one specific location, 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 scenario AF is 1.0 (in effect, no adjustment to the FIF 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 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 **critical area AF** based on the relative size of the floor space in the “critical” versus “plausible” locations: $AF_{\text{hot work}} = (\text{critical floor area, in ft}^2) / (\text{plausible floor area, in ft}^2)$

If hot work is improbable in the fire area and a thorough review of hot work permits issued verified no hot work was performed in the fire area under review during the exposure period, an AF of zero may be used for the hot work fire ignition source scenarios.

Finally, an adjustment to the FIF for hot work fires is made if the inspection findings are associated with hot work permitting and/or hot work fire watch provisions of the FPP. In this case the fire area hot work fire likelihood is set to high, and the hot work fire frequency for high likelihood is multiplied by a factor of 3.

03.10 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, 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.

03.11 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.

03.12 Hydrogen Fires

Hydrogen fires may occur as the result of leakage from hydrogen tanks, hydrogen piping, and bearing/seal surfaces 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.

0609F.3-04 GUIDANCE FOR IDENTIFYING AND CHARACTERIZING FIRE DAMAGE STATES

04.01 FDS 1

Develop a list of ignition and damage targets within the ZOI of the ignition source. **Screening values of the vertical and radial ZOI for electrical enclosures are given in Attachment 8, Table A.01. Screening values of the vertical and radial ZOI for other fixed ignition sources and transient combustibles are given in Attachment 8, Table A.02.** The **vertical and radial ZOI** of combustible liquid fires can be determined from Figures A.02-A.07 and Figures A.08-A.13 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 **base of the fire**, or radial distance between the target and the edge of the ignition source.
- 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?

04.02 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 table/plot **set C** in Attachment 8. 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 (**or Figures A.02 to A.04 in Attachment 8 for confined pool fires and Figures A.08 to A.10 in Attachment 8 for unconfined spill fires**) 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 the first cable tray above **the ignition source ignites in one min**, and 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 **ZOI** 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 **D** 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 percent 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.

04.03 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.

0609F.3-05 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 **base** of the ignition source **fire** 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.

END

Attachment 1: Revision History for IMC 0609 Appendix F Attachment 3

Commitment Tracking Number	Accession Number Issue Date Change Notice	Description of Change	Description of Training Required and Completion Date	Comment Resolution and Closed Feedback Form Accession Number (Pre-Decisional, Non-Public)
	ML041700310 05/28/2004 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.		
	ML050700212 02/28/2005 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 DRAFT 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. CA Note sent 7/18/17 for information only, ML17191A681. Issued 10/11/17 as a draft publically available document to allow for public comments.	November 2017	ML17093A181
	ML18087A405 05/02/18 CN 18-010	Draft document revised to incorporate public comments to incorporate FAQ 13-0005 regarding self-ignited cable fires. New accession number required to issue as an official revision.	Gap training covering changes to the procedure completed November 2017	ML17093A181

Commitment Tracking Number	Accession Number Issue Date Change Notice	Description of Change	Description of Training Required and Completion Date	Comment Resolution and Closed Feedback Form Accession Number (Pre-Decisional, Non-Public)
	ML24145A030 09/05/24 CN 24-024	This revision includes updating IMC 0609 Appendix F, its associated attachments, and the basis document to incorporate updated guidance for modeling transient fires per NUREG-2233, high energy arching faults per NUREG-2262, and electrical enclosure, electric motor, dry transformer and main control room fires per NUREG-2178 Volume 2. This revision also implements the heat soak method in the HRR and ZOI calculations.		ML24155A258