Attachment 3

Guidance for Identifying
Fire Growth and Damage Scenarios

General treatment of localized fire barriers and raceway fire wraps

The following considerations will apply in assessing the damage potential for components or cables protected by a localized fire barrier wrap (e.g., a raceway fire barrier) or fire retardant coating:

- Components and cables will be considered fully exposed unless they are protected by a fire barrier with a specific fire endurance rating established in accordance with accepted standard testing protocols. Non-rated barrier systems are not credited.
- Components and cables protected by a non-degraded fire barrier with a minimum fire endurance rating of two hours will be assumed to invulnerable to fire damage unless the a high-hazard fire source (e.g., a large oil spill or oil-filled transformer) is identified that can result in a direct flame impingement exposure to the fire barrier.
- Components and cables protected by a fire barrier system with a minimum 1-hour fire protection rating installed as a part of the licensee's Appendix R III.G.2 separation criteria compliance strategy will be considered as fire damage targets (i.e., are subject to fire-induced failure) only if some aspect of the III.G.2 fire protection strategy is found to be degraded. The degradation may be associated with any aspect of the licensee's compliance strategy including the fire barrier itself, the automatic fire suppression system, the automatic fire detection system, or post-fire safe shutdown.
- Components and cables protected by a fire barrier system with less than 1-hour fire endurance rating are considered damage targets, but the fire barrier system will be credited for providing protection commensurate with the demonstrated fire endurance rating.
- Cables protected by a fire retardant coating are treated as exposed fire ignition and damage targets unless the coating has a specific demonstrated fire endurance rating. If the coating has such a rating, it is treated as a fire barrier consistent with the cases cited immediately above.
- Cables in conduits are considered exposed fire damage targets, but will not contribute to fire spread. A conduit is not a fire barrier.

Special consideration for direct flame impingement on a raceway fire barrier

The discussion above describes how cables and components protected by a local fire barrier wrap are treated for general fire scenarios. Beyond the conditions of a general fire scenario, one should be aware of potential performance issues under severe fire exposure conditions. In particular, if a high hazard fire source can create a direct flame impingement exposure condition, a raceway fire barrier may not provide protection against fire damage.

The commonly applied fire barrier qualification standard (e.g., ASTM E119 and associated subsidiary documents) involves the exposure of a fire barrier system to relatively harsh temperature conditions. However, the standard test does not involve direct flame impingement which can create a far more severe exposure condition. Hence, the performance of a fire barrier system is not assured should the fire exposure conditions involve direct flame impingement from a high hazard fire source.

Example 1: Redundant safe shutdown cables routed below the main turbine generator set are protected by one hour raceway fire barriers. In the event of a severe fire involving a spill of oil from the lube oil system, the raceways may be exposed to direct flame impingement conditions.

Example 2: Redundant safe shutdown cables are routed directly above an oil-filled transformer. The cables are protected by a three-hour fire wrap. In the event of a catastrophic transformer fire, the cable raceways might experience direct flame impingement. If a situation exists where raceway fire barriers are being applied in an area with high hazard fire ignition sources such that direct flame impingement on the barriers is possible, a Phase 3 analysis may be warranted. In such cases, it is recommended that additional Agency fire PRA support be sought in the analysis of such configurations.

<u>General Rules for Developing Fire Scenarios</u>

One must have an ignition source - something which can start a fire - and a package of fuel which can be ignited. Lacking either of these, there is no credible scenario. Often both the ignition source and the initial fuel package are inherent elements of an electrical component. In other cases (e.g., transients, a spill of oil) if there is a fuel package available, it will be assumed that a fire ignition source may be introduced such that the fire will be ignited. The fire event frequency statistics inherently reflect the probability that such fires do occur in actual plant experience; therefore, the review does not explicitly focus on identifying a specific source to actually ignite a fire. Rather, the review focuses on identification of fire ignition sources as a consolidated ignition/initial fuel package. The likelihood that ignition actually occurs is based on the event data, consistent with operating with the fire frequency estimates provided for various fuel packages. However, if no fire ignition sources exist in the fire area, then no fire scenarios can be developed excepting transient fires.

- IEEE-383 rated low flame spread cables are not an ignition source so long as protective devices (fuses or circuit breakers) are analyzed to be properly sized (no self-ignited cable fire will be postulated).
- For small combustible liquid fires (less than one gallon) damage is postulated only if the target is in the plume or suffers direct flame impingement.
- Fires inside solid metal cabinets will remain within the cabinet, unless the cabinet is vented (i.e., has ventilation grills or openings), cable penetrations into the cabinet are not sealed (e.g., in the top of the panel), and/or combustibles are in direct contact with the cabinet (exception - arcing faults).
- High energy electrical faults (arcing faults at 440VAC and higher) can propagate damage outside solid metal cabinets. In such cases, the panel will be assumed breached by the initial fault.
- For ventilated cabinets, the zone of influence chart is applied to determine the damage/ignition zone. In such cases, the origin of the fire is placed at 1 foot below the top of the cabinet.
- For a combustible liquid fire, the fire origin for the zone of influence chart will be placed at the surface, and the width of the zone of influence will cover the entire surface of the pool.
- For ordinary combustibles (paper, wood, anti-contamination clothing, rags, plastic) the fire origin is placed 2 feet above the floor at the center of the postulated location.
- Exposed oil-soaked rags and paper can be considered a source of spontaneous combustion.

- Transient combustibles for fire scenarios can be assumed to be the maximum amount for which a permit is not required, or the actual amounts identified during the inspection, whichever is greater.
- Oil in closed bearing housings does not contribute to a fire.
- Lubricating oil in a “wicking” configuration (oil-soaked insulation, oily rags) will ignite at temperatures as low as 500/F

Specific Considerations for Development of Scenarios for Spreading Fires

In Step 2.3, the nearest secondary combustible material to a given fire ignition source was identified. Given that the fire ignition source survived screening, it is likely that this material will be ignited during the fire. Three exceptions might exist:

- Presence in the fire area of a thermally fragile damage target (e.g., a solid state circuit board) that is damaged but not ignited,
- A case involving no direct path for fire spread, but a source of sufficient intensity to create a damaging hot gas layer, or
- A case involving cables within a conduit that are damaged by the fire but do not contribute to fire spread, and where no other fire spread paths were identified.

Assuming that the ignition of at least one secondary combustible material was determined to be credible, it is then necessary to postulate the further spread of the fire, assuming that the fire remains unsuppressed. Direct paths for fire spread are sought. That is, the fire will not be assumed, a-priori, to ultimately engulf all combustible materials in the fire area unless credible paths and mechanisms for fire spread can be identified.

The specific fire damage scenarios (i.e., fire damage target sets) corresponding to each FDS of interest will also be identified. The identification of fire damage scenarios requires the identification of specific component and cable damage targets that will be assumed to be failed as a result of the corresponding fire growth scenarios.

The fire damage target sets may be unique to each fire ignition source scenario, or may be common to two or more fire ignition source scenarios. In some cases, the same fire damage target set may apply to all fire ignition source scenarios in the fire area. The ability to refine fire damage sets to specific fire scenarios is often driven by the level of cable and component routing information available.

> Example 1a: Assume that cable routing information available is of sufficient detail to distinguish the location of a specific target cable within a specific set of cable trays in the fire area. In this case, the fire damage target set to individual fire ignition sources can likely be tailored based on the proximity of the specific target cables.

> Example 1b: The availability of detailed cable routing information may be used as a basis for defining multiple damage target sets for a given fire ignition source scenario. In such cases, the target sets should be cumulative - adding new targets as the fire damage spreads within the fire area. The first damage target set might involve only the first target cable. A second set may involve the same first cable plus a second cable, and so forth. (In practice, the final risk quantification will often be dominated by one of the identified fire damage target sets. This will

be one potential outcome of Step 2.8.) In such cases, judgment is applied in assessing when a fire has progressed from FDS1 to FDS2.

Example 2: Assume that cable routing information is sufficient to identify that one or more cables associated with a potential target system are located within the fire area, but their specific routing within the fire area is not known. In this case, the target set for all unscreened fire ignition source may be assumed to include these cables. The location of the target cable will be assumed to be in the tray (or conduit) nearest each fire ignition source barring other information suggesting this assumption is excessively conservative (e.g., assuming that a power cable is in a nearby tray containing only instrument cables).

NOTE: Additional cable or component routing information beyond that provided by the licensee is not expected to be gathered. The cable and component routing information provided by the licensee is expected to be utilized.

NOTE: Even given a spreading fire, with the application of specific cable and component routing information, one may be unable to identify a potentially risk-important set of fire damage targets for a given fire ignition source. This can result in the screening of specific FDS scenarios associated with a given source, or in the screening of a fire ignition source in its entirety.

Example 3a: If cable routing information demonstrates that none of the cables directly above a fire ignition source are potentially risk important, then that fire ignition source may be incapable of producing a potentially risk important FDS1 fire scenario. The potential for FDS2 and FDS3 scenarios should still be considered (consistent with the results of Step 2.3).

Example 3b: Continuing example 3a, it is determined that there is no direct path for fire spread beyond the cables directly above the fire ignition source, and (using the hot gas layer temperature tool) that burning of the fire ignition source in combination with those cables that are overhead is insufficient to create a damaging hot gas layer exposure. It is therefore concluded that no FDS2 scenarios are credible for this ignition source. Should one be unable to define any credible and potentially risk-important fire growth and damage scenarios for a given fire ignition source, then that fire ignition source may be screened out from further consideration (i.e., in the same context that other fire ignition sources may have been screened out in Step 2.3). Having screened out one or more fire ignition sources, the screening check in Step 2.4 (Task 2.4.4) should be repeated if these sources were a significant contributor to the area fire frequency.

<u>Rules for Development of Cable Tray Fire Scenario</u>

- Fires in horizontal cable trays spread along the tray at the rate of ten feet per hour.
- Thermoplastic cables and ordinary combustibles (e.g., paper, wood) exposed to temperatures of 400°F can be considered to be ignited
- Thermoset cables exposed to temperatures of 625°F can be considered to be ignited.
- 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 spread of fire within the stack will be assumed to spread as follows:
  - Exposure source to first tray: tray ignites at time to damage/ignition using the plume temperature correlation
  - First tray to second tray: 4 minutes after ignition of first tray

- Second tray to third tray: 3 minutes after ignition of second first tray
- Third tray to fourth tray: 2 minutes after ignition of third tray
- Fourth tray to fifth tray: 1 minute after ignition of fourth tray
- Balance of trays in stack: 1 minute after ignition of fifth tray

- Spread to adjacent trays:
  - If there is a second stack of cable trays next to the first stack, spread to the first (lowest) tray in the second stack will be assumed to occur concurrent with spread of fire to the third tray in the original stack (i.e., 7 minutes after ignition of the first tray in the first stack).
  - Subsequent spread of fire in the second stack will mimic the continued growth of fire in the first stack (e.g., the second tray in the second stack will ignite within 2 minutes of the first tray in the second stack - at the same time as the fourth tray in the first stack.)
  - Fire spread will occur at the same rate to stacks on either or both sides of the original tray stack.

Specific Considerations in the Development of Scenarios for Non-Spreading Fires

In the case of non-spreading fires, it is determined that there is no basis for defining a fire spread path beyond the fire ignition source itself (i.e., there are no exposed combustible materials within the fire ignition sources zone of influence). In this case, a damage target set should still be identified, if possible. Such sources will have been retained in Step 2.3 only if they were capable of causing damage to at least one identified fire damage target. The full range of fire damage targets that might be damaged will be identified.

- Hot Gas Layer Scenarios: If fires involving a specific fire ignition source are of sufficient intensity to cause hot gas layer damage to cables and/or components in the area, then all vulnerable cables and/or components will comprise the fire damage target set. Such target sets will be considered in the context of FDS2 fire scenarios; therefore, components and cables protected by a non-degraded fire barrier system of at least one-hour fire endurance duration will not be considered vulnerable. All unprotected cable and components will be considered vulnerable. Damage to cables and components protected by a degraded barrier system will be considered vulnerable consistent with the assigned degradation rating (e.g., based on the time of protection).

- Scenarios involving damage to cables in conduit: As noted in Step 2.3, cables in conduit are considered potential damage targets, but do not contribute to fire spread or intensity. Therefore, if a specific fire ignition source has the potential to damage cables in conduit, then these cables become the fire damage target set. No fire spread path is assumed. Fire damage may involve FDS1 and/or FDS2 scenarios depending on whether any of the target conduits are wrapped with fire barrier materials that were found degraded. The zone of influence charts used in Step 2.3 can be used to identify potential damage targets within reach of the non-spreading fire.

- Scenarios involving thermally fragile damage targets: In the case of non-spreading fires that can damage thermally fragile fire damage targets, the treatment parallels the treatment of hot gas layer scenarios.

NOTE: Given a non-spreading fire, and the application of specific cable and component routing information, one may be unable to identify a potentially risk-important set of fire damage targets. For example, the nearest damage target may prove to be unimportant, and other potentially important damage targets may not lie within the fire ignition source's zone of influence. In such cases, the non-spreading fire ignition source may be screened out from further consideration (i.e., in the same context that other fire ignition sources may have been screened out in Step 2.3). The screening check in Step 2.4 (Task 2.4.4) should be repeated if the newly screened out fire ignition source was a significant contributor to the area fire frequency.

Special Considerations for FDS3 Scenarios

For guidance on the defining FDS3 fire scenarios, see Attachment 7 – Guidance for Fire Growth and Damage Time Analysis.