ARC MAPPING
Things to Consider

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INTRODUCTION

A great deal has been written about Arc-Mapping and its effectiveness in identifying the origin of a fire, dating back to the early 1970’s. [1] The concept is based on the premise that fire attacks the insulation on the electrical conductors in close proximity to where the fire originates, causing abnormal electrical activity such as an arc fault between the electrical conductors, which, in turn, trips the overcurrent protection and produces characteristic damage that may be recognized after a fire. Once the overcurrent protection operates, the circuit being examined is no longer energized, and no further arcing will occur on that circuit. In theory, “evidence of this [abnormal] electrical activity may be useful in locating the area of origin”. [2]

There are many factors that influence the reliability of Arc-Mapping, however, and very little has been published that specifically addresses such factors (or concerns). Consideration must be given to such things as fire loads, level(s) of protective coverings over the wiring, and ventilation effects, to name a few, which can adversely affect the reliability of Arc-Mapping. To that end, a series of full-scale compartment fires were conducted in which energized electrical conductors were exposed to fire conditions. After the fires were extinguished, electrical activity on the conductors was identified and mapped to determine its relationship to the origin of the fires.

In an effort to produce differing fire growth scenarios, a variety of solid fuel arrangements were positioned throughout three burn cells, and differing levels of protective covering was applied over the electrical wiring. Some were covered with gypsum wallboard, while others had -inch wood paneling, and others had no protection whatsoever covering the wiring.

The burn times were determined by the activation of the overcurrent protection at the electrical distribution panel, at which point the fires were extinguished. As a result, the level of fire growth varied in each of the experiments.
EXPERIMENT #1

Photo 2 - View of Left side, Cell 1

During this experiment, the non-metallic cables were affixed to the gypsum wallboard and exposed to the heat from the fire without any protective covering over them. This scenario was designed to simulate an unfinished area, such as a basement or a portion of a dwelling at various stages of construction. (See photographs 2 through 4)

In this experiment, Quadrants 1 & 2 had equal fire loads, consisting of a full-sized mattress in each, and solid wood furniture in the remaining two quadrants. (See photograph 4 and Fig. 1)

Photo 3 - View of Rear Side, Cell 1

Photo 4 - Quadrants 1 & 2

Fire Load Arrangement – Cell 1

The fire was set by applying an open flame to the side of a mattress at the extreme left-rear corner in Quadrant #2 and allowed to burn for a period of 4 minutes, 34 seconds until the over-current protection tripped at the panel. The compartment reached a temperature of 442°C (829°F) and was extinguished before reaching flashover. (See photographs 6 through 8)

Fire Growth – Burn Cell #1

Photo 5 - Quadrants 3 & 4

Photo 6 - Fire started at “B-C” corner

Photo 7

Photo 8

Electrical arcing between the hot and neutral conductors was located on each of the energized circuits, and their locations were documented with orange marking tape. The evidence of arcing was found along the ceiling at the rear portion within Quadrants 2 & 3, extending across the entire length of the ceiling with arcing located immediately over where the fire originated, as well as at the right-rear corner opposite the doorway opening. (See photographs 9, 10, and Fig. 1)

…continued on page 20
EXPERIMENT #1 continued

Photo 9 - Quadrant #2
(Facing B/C Corner)

Photo 10 - Quadrants 2 & 3
(Facing Side–C, opposite doorway)

EXPERIMENT #2

During this experiment, non-metallic cables were affixed to the gypsum wallboard with all electrical wiring on the walls then covered over with ½-inch gypsum wallboard to shield them from the heat. The wiring across the ceiling in Quadrants 1 & 2 was also covered with ½-inch gypsum wallboard. The wiring in Quadrants 3 & 4 was covered over with ¾-inch wood paneling to provide for differing levels of protective covering over the electrical wiring than those in Quadrants 1 & 2. The scenario was designed to simulate a dwelling where various construction materials are used. (See photograph 11). The fire load consisted of an overstuffed sectional sofa and a wood desk in Quadrants 1 & 2, and a solid wood dresser in Quadrants 3 & 4. (See photographs 13 & 14 on page 21)
Fire Growth – Burn Cell #2

The fire was set in Quadrant 1 by applying an open flame to crumpled newspaper that was positioned adjacent to the sectional sofa and immediately beneath cotton draping attached to the B-side wall. The fire was allowed to burn for a period of 5 minutes, 1 second until the over-current protection tripped at the panel. The compartment reached temperatures of 454°C (850°F) and was extinguished before reaching flashover. (See photographs 15 through 19)

Fire Load Arrangement

EXPERIMENT #2 continued

Electrical arcing was identified on the energized circuits, and their locations were documented with orange marking tape. Evidence of arcing was found at ceiling level within Quadrant 3, immediately opposite the doorway opening with no arcing located near where the fire was started. (See photographs 20 & 21, and Fig. 2 on page 22)
**EXPERIMENT #2 continued**

Arc Mapping – Burn Cell #2

During this experiment, non-metallic cables were affixed to the underside of the gypsum wallboard, and all electrical wiring was then covered with ½-inch gypsum wallboard to shield them from the heat, which provided equal protection over all energized circuits. This scenario was designed to simulate a room of standard construction.

Fire loads in Quadrant 1 consisted of a combination of a solid wood desk, chairs and fabric-covered furniture. Crumpled newspaper was arranged along the floor in Quadrant 2 against the side of a wood bookshelf, which was positioned immediately adjacent to an overstuffed chair. The fire load in Quadrants 2 & 3 consisted of an overstuffed chair and pullout sofa bed with an assortment of bedding material. The fire load in Quadrant 4 consisted of a wood room-divider and a solid wood bookshelf. The fire was set in Quadrant 2 by applying an open flame to the sheets of crumbled newspaper. (See photographs 24 through 32 and Fig. 3)
The fire was allowed to burn for a period of 11 minutes, 1 second at which time the overcurrent protection tripped at the panel. During this experiment, the compartment reached post-flashover conditions with temperatures exceeding 648°C (1,198°F) before being extinguished.

Electrical arcing was identified on the energized circuits and their locations were documented with orange marking tape. Evidence of arcing was found at ceiling level along the rear wall within Quadrant 2 immediately over the overstuffed chair, a short distance from where the fire started.

Fire started here
In experiment #1, where all electrical wiring was unprotected and equally exposed to the heat, Arc-Mapping proved to be useful in identifying the fire’s origin, which was easily verified by visible fire damage patterns. However, it is worth noting that electrical activity (arching) was also present in the area immediately opposite the ventilation opening, (At the C – D corner), which was a distance away from where the fire started.

In experiment #2, where the electrical wiring had a greater degree of protective covering (Gypsum) in Quadrants 1 and 2, and a lesser degree of protection over the wiring in Quadrants 3 & 4 (1/8-inch wood paneling), Arc-Mapping proved completely ineffective in identifying the origin. High velocity flows and turbulence from the ventilation opening intensified the fire in this location, which attacked the insulation on the electrical conductors early in the progression of the fire. This resulted in tripping of the overcurrent protection. Although proven to be an useful tool in the identification of an area of origin, a credible origin analysis hinges upon consideration of many factors, including the location(s) and configuration of fire load, the recognition and understanding of the influences of high velocity flows and turbulence from the ventilation openings, differing levels of protective coating over electrical wiring, as well as stages of fire growth attained.

As with any origin determination, investigators must be able to identify and then segregate fire scene damage that may potentially be attributed to pre and post-flashover fire conditions. In pre-flashover conditions, fire pattern analysis most often defines the origin, and Arc-Mapping is used as a tool to confirm what the patterns reflect. However, fire loads that influence heat release rates and burn damage within a specific localized area may produce evidence of arcing that is not associated with the fire’s origin.

Most notable in this experiment was the evidence of arcing found in areas opposite the ventilation openings where the fire did not originate. High velocity, turbulent flows opposite and around ventilation openings produce a concentration of high temperatures, which can impact electrical conductors if present in that area, thus produce arcing that, if misunderstood, could lead to an inaccurate origin being identified.

Therefore, for Arc-Mapping to be useful in identifying the origin of a fire, it is essential that investigators distinguish between the damage created by ventilation effects versus the damage created purely by fire attack around the location(s) where the fire started. Careful steps must be taken to ascertain the exact physical makeup of the compartment in terms of wall, floor and ceiling coverings, fuel packages and arrangements, window treatments, the conditions of ventilation openings and at which stage in the fire’s progression they were opened or failed. The failure to thoroughly investigate and consider these factors may lead to an erroneous origin.

In experiment #3, the fire burned in a localized area for a substantial duration where the fire started before fuel gases filling the compartment became involved. Arc-Mapping was useful in this experiment. However, the electrical activity was not found immediately over the fire’s origin, but rather in the general proximity. Electrical activity was also found opposite the ventilation opening, away from where the fire started. Once again, visible fire damage patterns clearly identified the origin.

Several important concepts were derived from the experiment with regard to the effectiveness of Arc-Mapping. Although proven to be an useful tool in the identification of an area of origin, a credible origin analysis hinges upon consideration of many factors, including the location(s) and configuration of fire load, the recognition and understanding of the influences of high velocity flows and turbulence from the ventilation openings, differing levels of protective coating over electrical wiring, as well as stages of fire growth attained.

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