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Hot Topics in Fire Investigation

I. Fire investigation developments in industry groups and standards

American Association for the Advancement of Science (AAAS) report

The American Association for the Advancement of Science (AAAS) issued a July 2017 report titled Forensic Science Assessments: A Quality and Gap Analysis Report 1—Fire Investigation & Annotated Bibliography. The AAAS is an international nonprofit organization and the report was authored by five interdisciplinary Working Group members including a forensic chemist, an academic fire engineer, an analytical chemist, and a psychologist who studies decision making. The focus on fire investigation was described as based on its common inclusion in criminal investigations and the "degree of current controversy", which was potentially related to wrongful convictions that had been overturned.[1]

The areas of interest identified in the report include the accuracy and consistency of origin and cause determination, the use of canines in locating ignitable liquid residues in fire debris, cognitive biases, and certification of fire investigators.

Organization of Scientific Area Committees (OSAC) findings

The Organization of Scientific Area Committees (OSAC) Subcommittee on Fire and Explosion Investigation issued Needs Assessments in 2016 covering two areas: the Potential for Reducing Bias in Fire and Explosion Investigations and the Validation of Origin and Cause Determination Protocols. The OSAC is a part of the National Institute of Standards and Technology (NIST) within the U.S. Department of Commerce and is intended to develop technically sound forensic science standards.[2]

The documents described research needs in the area of bias within fire investigations and the validation of methods used within the investigations. Similar to the AAAS report, these documents called for research into the effects of bias on fire investigations and the repeatability and uncertainty in origin and cause determinations.

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1 Almirall, J., Arkes, H., Lentini, J., Mowrer, F., and Pawliszyn, J., "Forensic Science Assessments: A Quality and Gap Analysis, Fire Investigation," American Association for the Advancement of Science, July 11, 2017.

2 https://www.nist.gov/topics/organization-scientific-area-committees-forensic-science

NFPA 921 and NFPA 1033

No discussion of fire investigation is complete without mention of the National Fire Protection Association (NFPA) documents NFPA 921, the Guide for Fire and Explosion Investigations, and NFPA 1033, the Standard for Professional Qualifications for Fire Investigator. Both documents are consensus based and have evolved with the current understanding of fire science since their introductions in 1992 and 1987, respectively.

Changes in the 2017 edition of NFPA 921 included updates to the limitations of arc mapping, the addition of an origin matrix analysis technique, and discussions of the importance of ventilation in fully involved compartment fires.[3] The next edition is expected in 2021.

II. Post-flashover fires

Flashover basics

Flashover is defined in NFPA 921 as a transition in a compartment fire when the combustibles within a room more or less simultaneously reach their ignition temperature resulting in the fire rapidly spreading throughout the space.[4] It can also be described more colloquially as when a fire in a room becomes a room on fire.

A fire that is suppressed at an early stage may result in fire damage patterns that can reliably be used to determine a small area of origin. In contrast, when a fully developed, post-flashover fire continues to burn for an extended length of time, the damage patterns within the room can become obscured and difficult to interpret.

Ventilation effects

The burn patterns resulting from fully developed, post-flashover fires can often be an indication of ventilation and oxygen availability rather than area of origin.[5] When a compartment fire becomes fully involved, the amount of oxygen within the room diminishes rapidly. The hot gases vent through openings of the structure and the most intense burning occurs at the location where the hot fuel gases meet sufficient oxygen levels to support combustion.[6] The resultant effect is an increase in the severity of the fire damage patterns near the areas where fresh ventilation meets the hot fuel gases.

Especially in post-flashover or fully developed compartment fires, the effects of ventilation can cause damage patterns that are not indicative of origin. Ventilation related patterns can destroy fire patterns that were formed earlier in the fire progression, masking information that would have been useful in determining fire origin. The ventilation in compartment fires can be complex and complicate the analysis of the fire spread. The location where the hot fuel gases mix with sufficient oxygen is not necessarily only near ventilation openings, but may be elsewhere in the compartment due to complex flows of air. In one study, the area of most intense damage was directly across the room from a ventilation opening, due to the inflow of fresh air in that specific configuration.[7]

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3 NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition

4 NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition, 3.3.89 Flashover.

5 Carman, SW, "Improving the Understanding of Post-Flashover Fire Behavior," Presented at the International Symposium on Fire Investigation Science and Technology, Cincinnati, OH. May 2008, p. 2.

6 DeHaan, J.D., "Kirk's Fire Investigation," Pearson Prentice Hall, 6th Ed., 2007, p. 53-54.

7 Carman, SW, "Improving the Understanding of Post-Flashover Fire Behavior," Presented at the International Symposium on Fire Investigation Science and Technology, Cincinnati, OH. May 2008

Post-flashover fire pattern analysis

Recent experimental work has shown that extreme caution must be used when assigning meaning to post-flashover fire damage patterns.[8] In a post-flashover fire, the effect of ventilation can create new burn patterns that result in an incorrect determination of the area of origin. If a post-flashover fire burns for a long period of time, then the observed fire patterns can be nearly identical regardless of the location of the area of origin within the compartment.[9] Determination of the origin of the fire is particularly important as "a fire cause determination can be considered reliable only if the origin has been correctly determined."[10]

In experiments performed by the U.S. Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF), less than 10% of participating career fire investigators were able to identify the quadrant of origin within a single compartment for a post-flashover fire (random selection of a quadrant would be expected to result in 25% of the participants selecting the proper quadrant of origin).[11] In response to this and other studies, the AAAS issued a 2017 Quality and Gap Analysis report on Fire Investigation, which warned that "post-flashover fires may create new ventilation-generated burn patterns while obscuring pre-existing burn patterns."[12] The report also added that "the longer a fire burns in a fully involved condition, the more difficult is the determination of the correct area of origin." The fire in the ATF experiments described above burned for seven minutes, two minutes past flashover.[13] The Encyclopedia of Forensic Sciences further recommended that:

> What should happen is that once a compartment is identified as having been fully involved, every potential ignition source in that room should be examined, unless there is some compelling evidence that allows the origin to be narrowed further than the entire confines of the compartment. An eyewitness to the beginning of the fire or perhaps a videotape of the fire might meet these criteria. Certainly, the simple traditional interpretation of fire patterns in such a situation is likely to lead to error.[14]

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8 Carman, SW, "Improving the Understanding of Post-Flashover Fire Behavior," Presented at the International Symposium on Fire Investigation Science and Technology, Cincinnati, OH. May 2008.

9 Cox, A., "Origin Matrix Analysis: A Systematic Methodology for Post-Fire Investigation and Analysis of Compartment Fires," Fire and Arson Investigator, Journal of the International Association of Arson Investigators (IAAI), Volume 64, Issue 1, July 2013.

10 NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition, 19.1.

11 Steven W. Carman, Paper Presented at the Interscience Communications 2009 Fire and Materials Conference, San Francisco, Cal.: Progressive Burn Pattern Development in Post Flashover Fires, 2009; Lentini, J. J., "The Evolution of Fire Investigation and its Impact on Arson Cases," Criminal Justice, Volume 27, Number 1, Spring 2012.

12 Almirall, J., Arkes, H., Lentini, J., Mowrer, F., and Pawliszyn, J., "Forensic Science Assessments: A Quality and Gap Analysis, Fire Investigation," American Association for the Advancement of Science, July 11, 2017, p. 6.

13 Lentini, J.J., "Fire Patterns and Their Interpretation", Encyclopedia of Forensic Sciences, (2013), vol. 3, pp. 396-405; Lentini, J. J., "The Evolution of Fire Investigation and its Impact on Arson Cases," Criminal Justice, Volume 27, Number 1, Spring 2012.

14 Lentini, J.J., "Fire Patterns and Their Interpretation", Encyclopedia of Forensic Sciences, (2013), vol. 3, pp. 396-405.

In post-flashover compartment fires that burn for an extended time, investigators should understand the limitations of fire patterns and exercise caution when narrowing an area of origin.

III. Arc mapping

Arc mapping basics

While the two reports, AAAS and OSAC, focused on the interpretation of fire patterns and biases, the fire investigation community has also been discussing the limitations of arc mapping. As NFPA 921 states in its section Arc Mapping Interpretations, Implications and Notes, "Research continues on this issue".[15] NFPA 921 identifies arc mapping as a technique that involves the evaluation of damage to electrical circuits that can be used in origin determination.[16] The method includes the identification of arc damage, the documentation and understanding of the electrical circuits involved, and an analysis of the relationship between the observed damage and circuits to the fire spread.

Although subtleties and limitations to the method exist, the general concept in a typical American electrical system is "[w]here multiple arcs are found on a single circuit and there is a sever arc closer to the supply than other arcs, then the downstream arcs occurred no later than the sever arc."[17] This concept can sometimes be used to provide information regarding the sequence of damage to specific locations on an electrical circuit.

Identification of arc marks

Arc mapping includes the identification of arc marks, the lack of arc marks, and other forms of damage such as thermal and eutectic melting. The ability to differentiate the damage types is essential to the successful implementation of the method. NFPA 921 provides some guidance on the visual identification of arc damage and includes the description of sharp demarcation between damaged and undamaged areas. Other methods such as radiographs, X-ray computed tomography, and other metallurgical methods have also been proposed as techniques to gather additional information about the suspected arc mark.[18] Contextual information, such as damage to adjacent components, can also be used in identification.

The absence of arc marks can also be an important consideration in the analysis. However, when sections of conductors are missing or are masked by thermal melting, it may not be possible to determine if arc marks pre-existed the other damage. Without the examination of all of the potentially energized conductors within the area, a complete arc map cannot be created. NFPA 921 states, "If a complete arc map is not performed in the fire damaged areas (portions of the building or portions of conductors not examined), conclusions drawn from the arc mapping are limited to the area that was actually examined."[19]

Limitations of arc mapping

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15 NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition, 9.11.7.5 Arc Mapping Interpretations, implications and Notes

16 NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition, 3.3.9 Arc Mapping.

17 NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition, 9.11.7.5.2.

18 NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition, 9.11 Identification of Arc Melting of Electrical Conductors.

19 NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition, 9.11.7.5.4.

When used appropriately, arc mapping can provide information useful in determining the origin; however, the specific situation will determine the applicability. The 2017 edition of NFPA 921 states "Full-scale, single-compartment testing has indicated that arcs may be more prevalent in the area of origin. However, there does not seem to be a direct correlation between the origin and arcing on conductors at the closest geometric point. Research continues on this issue."[20] A 2015 study showed that the location of arc sites, in a single room fire experiment, are not always directly related to the location of the fire origin.[21] The physical distance between evidence of arcing and a hypothesized area of origin alone is not confirmation that the area is the origin.

The electrical circuits within the area of interest need to be understood in order to make any conclusions about the observed damage, including their routing during the fire, circuit protection, and energized status. Electrical conductors that have been shielded from the fire by drywall or other items can be affected differently by a fire than conductors that are directly exposed. Other specifics about the electrical system, such as the predictable operability of circuit protection and many other factors, can also affect the analysis.

III. Litigation and insurance insights

Choosing and vetting experts

As with any case, assembling the right team is essential to success. From a defense litigation standpoint, choosing and vetting which experts that you wish to engage involves a multi-factor analysis. As a preliminary matter, costs and expenses incurred in the investigation always will play a role in the decision, but won't necessarily dictate the process.

One of the first considerations in expert retention is the severity of the loss involved. The severity of the property damage and the amount of damages that are potentially at issue can dictate the number of the experts initially engaged and their geographic proximity to the loss location. The extent of the potential loss is sometimes proportionate to the geographic area in which you might research for an expert. For example, if the loss involves a large industrial property loss or a death which was potentially caused by some rare piece of sophisticated equipment then a search for an appropriate expert could span the lower 48 states. Whereas, if it was a small residential fire loss without personal injury or death, then you might stay with a local expert to control costs.

Other considerations are based upon who your client is and the type of loss involved. If your client is a product manufacturer of some type of electrical device, then you almost certainly will want to look for a licensed electrical engineer with a C.F.I. of C.E.F.I. credential to participate in the initial fire scene examination. If your client manufactures chemicals, then you may need to seek out an expert with a chemical engineering background. Vehicle fires are sometimes challenging with respect to what type of expert to engage. Do you want to engage a cause and origin fire investigator, a mechanical engineer or an electrical engineer? You will need to question the potential expert to help you make the decision.

When choosing and vetting a specific expert, you of course would need to obtain the expert's curriculum vitae and obtain his or her Federal Rule 26 disclosures including the list of publications authored in the last ten years as well as a list of cases in which he or she has testified. You might want to also ask whether the expert has barred from testifying in a case

[20] NFPA 921 Guide for Fire and Explosion Investigations, 2017 edition, 9.11.7.5.1.

[21] Wheeler, D.M., "Arc Mapping-Things to Consider", Fire & Arson Investigator, July 2015, pp. 18-24.

based upon a Daubert challenge. Ask the potential expert if he or she has been engaged to investigate similar losses involving similar products that were found in the origin of the fire. Finally, be sure to ask for the expert's fee schedule and after running through a brief factual scenario of the loss, try and push for a verbal estimate of what it would cost to conduct the exam.

After your initial expert retention and fire scene exam, and as a fire investigation develops, it is very important to continually ask your experts if you need any additional experts of different disciplines or fields. For example, if the fire resulted in a death, it would be important to ask your cause and origin investigator or electrical engineer if retention of a fire protection engineer might be required to address potential failures in the smoke or fire alarm systems. Similarly, if the conclusion of the investigation is dependent on the metallic composition of an arc or a melt in a conductor, you need to ask your expert if further testing of it should be conducted by a metallurgist. Always seek out your experts' opinions to help you determine the future course of the investigation.