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A Model for Challenging Fire Cause Determinations

BY JOHN J. LENTINI

Introduction

When faced with the challenge of defending someone who has been accused of arson, counsel has several options, but unless there is overwhelming evidence to indicate that this was in fact an arson, *the first thing counsel should do is retain an expert.*

Arson is one of the few crimes for which it is necessary to first prove that a crime was committed. Many false accusations of arson have resulted in either civil or criminal litigation. As stated in the 2009 National Academy of Sciences report,

> The simple reality is that the interpretation of forensic evidence is not always based on scientific studies to determine its validity. This is a serious problem. Although research has been done in some disciplines, there is a notable dearth of peer-reviewed, published studies establishing the scientific bases and validity of many forensic methods.[1]

This description applies to all forensic disciplines, including fire investigation. Specifically related to fire investigation, the NAS report goes on,

> [M]uch more research is needed on the natural variability of burn patterns and damage characteristics and how they are affected by the presence of various accelerants. Despite the paucity of research, some arson investigators continue to make determinations about whether or not a particular fire was set. However, according to testimony presented to the Committee, many of the rules of thumb that are typically assumed to indicate that an accelerant was used have been shown not to be true. Experiments should be designed to put arson investigations on a more solid scientific footing.[2]

The problem is that fires are destructive, and the aftermath of an accidental fire can often look exactly the same as the aftermath of an intentionally set fire. This confounding fact has led to many false accusations, false convictions, and even a wrongful execution.

According to the National Fire Protection Association (NFPA), there were about 339,500 residential structure fires in the United States in 2019.[3] Of these, approximately 54,500 (15%) were declared to be intentionally set.[4] That means that every year, there are more than 50,000 chances for fire investigators to make a serious error. Even if the error rate is only 5%, that amounts to 2,500 miscalls per year. Given this author's experience, a 5% error rate is wildly optimistic.

So, the first question that counsel needs to address is: "Is this actually an arson fire?" Following that question, additional questions arise.

- Is this fire investigator actually qualified to render opinions?

- ❖ Did the investigator employ appropriate methodology in reaching his opinions?

- ❖ Is origin determination even a valid forensic science discipline? (So far, attempts to demonstrate the validity of origin determination have failed.)

For all these questions, counsel must keep in mind that when proffering expert testimony, the proponent of the expert and his opinion must prove by a preponderance of the evidence that the expert is qualified, and his methodology is reliable. *The burden of proof is not on the challenger.*

Is This Really an Arson Fire?

Fire behavior is very complicated. Everyone thinks they know about fire because they know that "heat rises." That is only true until the heat encounters a ceiling. The investigation of fires was historically practiced by firefighters and police, rather than scientists, and when the first edition of NFPA 921 *Guide for Fire and Explosion Investigations* was published in 1992, the discipline was described as "a complex endeavor involving both art and science."[5] By the fourth edition of NFPA 921 in 2001, the sentence was changed to read "a fire or explosion investigation is a complex endeavor involving skill, technology, knowledge, and science."[6]

As more scientists entered the field and more experiments were conducted, researchers learned that many of the "indicators" of arson that had been relied on to obtain thousands of convictions (or civil verdicts for insurance carriers) were largely invalid. If an arson determination is based on "low burning" or a fire that burned "hotter than normal" or "faster than normal," or was based on the appearance of "pour patterns" on a floor without a positive finding of an ignitable liquid in a laboratory test, it needs to be treated with great skepticism.

If the only evidence of arson is the finding of a medium petroleum distillate on a hardwood floor, such a finding is not meaningful in the absence of a comparison sample that tested negative.[7]

By the turn of the century, it became generally accepted that NFPA 921's approach to fire investigation using the scientific method was the *only* valid means of determining whether a fire was, in fact, intentionally set.

Thus, it is always incumbent upon counsel to try to determine whether there is an accidental explanation for the fire. Such an effort almost always involves consulting a fire investigation expert.

Is the Investigator Qualified?

The starting point for this inquiry is the investigator's curriculum vitae (CV) and testimony history. There is often a fair amount of "puffery" on CVs. Is the investigator certified? Does he double count his certifications by referring to the Pro-Board accreditation of the International Association of Arson Investigators (IAAI) Certified Fire Investigator (CFI) program? Does he claim "certification" each time he got a certificate for attending a training course? Exposing such puffery or fraud can go a long way in discrediting an expert.

Federal Rules of Evidence Rule 702 applies to testimony by expert witnesses, and except in the rarest of cases, proving the fact that fire was intentionally set is going to require an expert witness to so opine. Rule 702 states,

"A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if

a. the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;

b. the testimony is based on sufficient facts or data;

c. the testimony is the product of reliable principles and methods; and

d. the expert has reliably applied the principles and methods to the facts of the case.

The qualifications of the expert are thus *the first thing* that should be explored both for strategic and tactical reasons. A significant number of fire investigators do not meet the definition of someone who is qualified. There is an industry standard known as NFPA 1033, *Standard for Professional Qualifications for Fire Investigator.* This standard, which is only 28 pages long, applies to anyone who investigates fires. NFPA 1033 lists 16 subjects in four categories that a fire investigator is *required* to have current knowledge in as they relate to fire investigations in order to be qualified according to this *minimum* standard. The 16 topics are:

1. **Fire science:**
   a. Fire chemistry
   b. Thermodynamics
   c. Fire dynamics
   d. Explosion dynamics

2. **Fire investigation:**
   a. Fire analysis
   b. Fire investigation methodology
   c. Fire investigation technology
   d. Evidence documentation, collection, and preservation
   e. Failure analysis and analytical tools

3. **Fire scene safety:**
   a. Hazard recognition, evaluation, and basic mitigation procedures
   b. Hazardous materials
   c. Safety regulations

4. **Building systems:**
   a. Types of construction
   b. Fire protection systems
   c. Electricity and electrical systems
   e. Fuel gas systems

NFPA 1033 provides detailed descriptions (and limitations) of these topics in Annex D.

NFPA 921 defines fire as "a rapid oxidation process, which is a chemical reaction resulting in the evolution of light and heat in varying intensities." Light and heat are forms of *energy*, so it only makes sense that a fire investigator should be able to describe the basic units of energy. Many do not know that the basic units of energy are joules.

Energy can be given off rapidly or slowly, and the *rate* at which energy is given off is known as *power.* Power is measured in watts, kilowatts, or megawatts, but there are many fire investigators who cannot state that one watt is the amount of power equal to one joule per second.

Just as important as power is the concept of how much *area* that power is spread out over. Thirty-six kilowatts of power spread evenly throughout a structure by a furnace's circulation fan will keep it comfortable on a cold winter day. Confining or focusing that energy, say to the

furnace closet, will result in dramatically different consequences. *Heat flux* is defined as power per unit area. Heat flux is measured in kilowatts per square meter or watts per square centimeter. A fire investigator should know that, but many of them do not.

Fire investigators should also have some knowledge of common fuel gases such as natural gas and propane. Many fire investigators have no clue that the chemical formula for methane, the main component of natural gas, is CH_4 or that the chemical formula for propane (LP gas) is C_3H_8. Investigators who do not know this simple fire chemistry can also probably not discuss why propane is heavier than air and methane is lighter than air, or tell someone how much air is required to burn a cubic foot of natural gas or how much energy would be released when that happens.

A *simple quiz* will allow counsel to determine whether a fire investigator is qualified as required by NFPA 1033. And although it may be uncomfortable, defense lawyers should apply this simple quiz to their own expert. If he is unable to pass this quiz, counsel might want to think about finding an expert who understands these really basic concepts. Space does not allow for the inclusion of the quiz here, but a longer version of this article, containing the quiz in a sidebar, is available in the *Lincoln Memorial University Law Review* (Fall 2020): https://digitalcommons.lmunet.edu/lmulrev/vol7/iss2/1/.

Exploring an investigator's qualifications is a simple matter in cases in which depositions are allowed. This includes almost all jurisdictions with regard to civil cases, but there are only a handful of states that allow depositions in criminal cases, and they are not allowed in federal criminal cases. When depositions are not allowed, an investigator's qualifications can be explored outside the presence of the jury in an evidentiary hearing. Evidentiary hearings are highly recommended whenever a question exists about the origin and cause of the fire. There are even cases where a criminal defendant can file some kind of civil case so as to provide an opportunity to depose the public sector witnesses in a criminal case.

Once an investigator fails a simple quiz, it is often not even necessary to move to exclude his testimony. Sponsoring counsel will do that when he or she recognizes what a disaster it would be to present such a person as an expert.

Only *after* a fire investigator's qualifications have been explored is it appropriate to explore the methodology used to reach the proposed opinion. Investigators who have demonstrated a lack of qualifications are likely to become somewhat rattled and unsure of themselves, which is why the qualifications challenge should come first. Whether they are qualified or not, fire experts are probably confident. If this confidence can be shaken, the expert will be less convincing to the court and the jury.

Did the Expert Use Appropriate Methodology?

NFPA 921 has been *generally accepted* as the appropriate methodology for conducting fire investigations since 2000. It was that year that the IAAI formally urged the adoption of the new edition of NFPA 921 by the NFPA,[8] and it was also in that year that the U.S. Department of Justice published *Fire and Arson Scene Evidence, A Guide for Public Safety Personnel.* This DOJ guide advises that in any large loss or any loss that is believed to be incendiary,

> ... the investigator should recognize limitations of his or her own expertise and knowledge and determine what personnel may be required to process the scene according to NFPA 921 and other recognized guidelines. Except in the most obvious cases, the determination of a fire's origin may be a complex and difficult undertaking that requires specialized training and experience as well as knowledge of generally accepted scientific methods of fire investigation.[9]

So, counsel should always ask the expert if he or she followed NFPA 921. The answer will almost always be yes, even if that is not the case.

One of the most common ways that investigators violate the guidance of NFPA 921 is in the use of *negative corpus* methodology. Such thinking usually results in a determination that the fire was intentionally set, although as the *Weisgram* and *Truck* cases (*infra*) demonstrate, negative corpus methodology can also be used to reach a conclusion that a fire was accidental. In arson cases, the thinking goes like this: "I can't find any accidental ignition sources that could cause this fire. Therefore, it must have been intentionally set with an open flame and the perpetrator took the ignition source away." In the case of an accidental cause hypothesis, the investigator simply states, "Everything else was ruled out," even when there is no affirmative evidence to support the fire investigator's hypothesis.

Negative corpus methodology is a result of expectation bias. NFPA 921 says the following about negative corpus thinking:

> This process is not consistent with the scientific method, is inappropriate, and should not be used because it generates untestable hypotheses, and may result in incorrect determinations of the ignition source and first fuel ignited.[10]

In addition to negative corpus methodology, other missteps include reliance on unconfirmed canine alerts (see the *Carr* case, *infra)* and believing that fire patterns in a fully involved room can be attributed to ignitable liquids on the basis of visual appearance alone. An erroneous cause determination usually involves believing in more than one discredited "indicator."

Counsel should explore the investigator's history to bring out evidence of bias. How many fires has this expert investigated? Were all of those conducted for law enforcement? Or were all of those conducted for insurance companies? Has the expert ever investigated a fire on behalf of a criminal defendant or a plaintiff in a first party arson case? Of the fires the expert investigated, how many has the expert determined to have been intentionally set?

One way to probe an investigator's biases is to ask him what opinions he has and *when* those opinions were formed. While it is impossible to "unsee" a "For Sale" sign in the front yard, investigators should not be considering motive until *after* determining that the fire was intentionally set. Table 1 shows two lists of factors, one relevant and the other potentially irrelevant. If the task is simply to determine the origin and cause of the fire, considering irrelevant data prior to determining the cause will frequently result in erroneous findings. Investigators should take steps to shield themselves from biasing information like that in the "potentially irrelevant" column until it is time to develop a suspect. Suspect development should only take place once it has been determined that a crime has been committed.

Data Sources that usually do not include irrelevant data	Data Sources that may potentially include task irrelevant data
Firefighters' observations relevant to the fire, scene security, and suppression activities	Financial records
Witness observations and photos/ videos relevant to the fire and building contents	History of fires
Occupancy	Criminal record
History of defects	Claim file
Weather data	Marital strife
Pre-fire activities on the scene	Social media commentary
Ignitable liquid location	Gossip
Physical condition of the fire scene	Motive issues
Utilities	Financial strife
Victim injuries	House for sale – real estate activity
	Indications of deception or emotional state of the victim
	Personal records

Table 1. Task relevant data and sources of potentially irrelevant data for origin and cause determination. Irrelevant data are generally related to motives.[11]

There have been thousands of *Daubert (*or *Frye)* challenges to fire investigators, more so in civil cases than in criminal cases, but filing a *Daubert* challenge in a civil case is almost considered due diligence and every fire investigator, no matter how qualified, is likely to see such a challenge if he goes to court often enough. Because of the deferential standard for review of a trial court's admissibility decisions (abuse of discretion), the record of appellate rulings is far smaller than the record of trial court rulings. There is a website, https://www.dauberttracker.com, that includes both trial court and appellate court rulings in *Daubert* challenges. This article will focus on four seminal appellate court cases that have impacted the admissibility of fire investigation testimony.

State of Georgia v. Weldon Wayne Carr[12]

This case arose out of an April 7, 1993, fire in Atlanta, Georgia, at the home of Weldon and Patricia Carr. Mr. Carr was convicted after being prosecuted by Nancy Grace in her last major court appearance before becoming a talking head for CNN.

The Georgia Supreme Court found many instances of prosecutorial misconduct ("We wish to register our stern disapproval of tactics…") and other reversible error, but the case was overturned primarily because the trial court admitted evidence of 12 unconfirmed canine alerts for ignitable liquid.

The Court granted Mr. Carr a new trial, but none of the Fulton County prosecutors assigned to the case wanted to try it. They were aware that many holes had been poked in the State's case, and after several years, the actual cause of the fire was determined to be a malfunctioning light switch. Some four years after the conviction, the indictment was dismissed because of the State's failure to provide a speedy trial.

Michigan Millers Mutual Insurance Company v. Janelle Benfield[13]

This was the first *Daubert* challenge of a fire investigator's opinion in an arson case.

The fire occurred on July 6, 1992, at Mrs. Benfield's residence in Sarasota, Florida. Mrs. Benfield discovered the fire, which had burned itself out, when she returned home from a friend's house where she had fled her abusive husband.

The fire was an obvious arson, but because the private fire investigator, who called himself a "fire scientist," was unable to articulate the scientific method, his testimony was excluded. This case was appealed to the Eleventh Circuit, which ruled that the judge did not abuse his discretion by eliminating the testimony, but he did abuse his discretion by entering the directed verdict because there was a firefighter who did not claim to be a fire scientist, who stated that "based on his experience," it was his opinion that the fire was intentionally set.

The Eleventh Circuit ruling had the curious effect of prosecutors and insurance defense attorneys encouraging fire investigators to avoid using the word "science" in their reports or testimony. Apparently, the Eleventh Circuit misread the *Daubert* decision and ruled that if one claimed to be a fire scientist, one was subject to a *Daubert* reliability challenge, but if one claimed only to be a fire investigator, a *Daubert* challenge was not appropriate.

This decision was overturned by a unanimous Supreme Court in the *Kumho* case, which also originated in the Eleventh Circuit.[14] *Benfield* resulted in the production of an *amicus* brief by the IAAI in 1997 which argued that because fire investigation was a "less scientific" discipline, fire investigators should not be subjected to reliability challenges.[15]

When I read the IAAI's *amicus* brief, I found it necessary to file my own, which was submitted to the Eleventh Circuit but strongly objected to by Michigan Millers. The case eventually settled, but not before thoroughly shaking up the world of fire investigation.

Weisgram v. Marley[16]

This case arose out of a December 30, 1993, fire in Fargo, North Dakota. The fire was discovered around 6 a.m. and was fatal to Bonnie Weisgram. The main fuel involved in the fire was an L-shaped sofa in the living room, but a sofa cushion was found in the entryway, where there was additional fire damage. A disabled smoke alarm was found on the floor with a protection pattern under it, indicating it had been taken down prior to deposition of smoke on the carpet.

The court allowed three experts to testify that the fire was caused by an electric baseboard space heater that had operated without incident for 15 years. There were other improbable conclusions presented. One of the experts was Ralph Dolence, an electrician from Ohio, who claimed on more than one occasion to have conducted

15,000 fire investigations in 22 years.[17] (Do the math.) The Eighth Circuit found that the trial court had erred in allowing their testimony. The court entered a judgment for Marley as a matter of law.

Weisgram appealed to the U.S. Supreme Court, which took the case to decide if the Eighth Circuit should have granted the plaintiffs a new trial with new experts. The Supreme Court decided that the judgment was appropriate and that to rule otherwise would have given plaintiffs a second bite at the apple. This case was significant in that three experts were excluded or limited, all for different reasons, in one case.

Truck Insurance Exchange v. Magnetek[18]

This was a product liability subrogation case. A fire on November 9, 1998, in Lakewood, Colorado, destroyed Sammy's Restaurant. Upon arrival, the fire department found only smoke, no fire, until the fire caused the kitchen floor to collapse, indicating a fire in the basement. There was a fluorescent light in the basement and, according to the experts, no other potential ignition sources. Thus, the light was the cause. (Clearly, this was a *negative corpus* determination.) The ballast in the light, manufactured by MagneTek, still contained a thermal cut off (TCO), which still functioned after the fire. It opened at 232° F. A similar ballast when shorted, i.e., the TCO was bypassed, reached a stable temperature of 300° F. The ignition temperature of wood is well in excess of 400° F.

There is a never-proven hypothesis that upon continued exposure to a heat source below its ignition temperature, the ignition temperature of wood is lowered to a point where a heat source of only 200° F might ignite it.

MagneTek moved for summary judgment and the exclusion of the plaintiff's electrical engineer. The trial court granted the motion and Truck appealed to the Tenth Circuit, which upheld the exclusion. In its ruling, the appellate court adopted some unfortunate terminology, which points out the problems with having judges act as scientists. The Tenth Circuit stated,

> There appears to be some confusion among the parties, the District Court, and apparently even the scientific community as to the proper terminology for the theory of long-term low temperature wood ignition and the charring it involves. This court is not in a position to decide such questions for the scientific community but for the purposes of this opinion we will refer to this process as "pyrolysis." To the extent we use the term "pyrophoric carbon," we are talking about the substance charred wood.

The Tenth Circuit held that the District Court did not abuse its discretion when it ruled that under the *Daubert* trilogy, "pyrolysis" was not yet a sufficiently reliable theory upon which to base an expert opinion about the cause of the Sammy's fire. The only problem with this ruling is that the "shorthand" caused much consternation in the fire investigation community. Pyrolysis *always* happens when wood burns. It must. Judges cannot change the laws of chemistry!

Is Origin Determination a Valid Discipline?

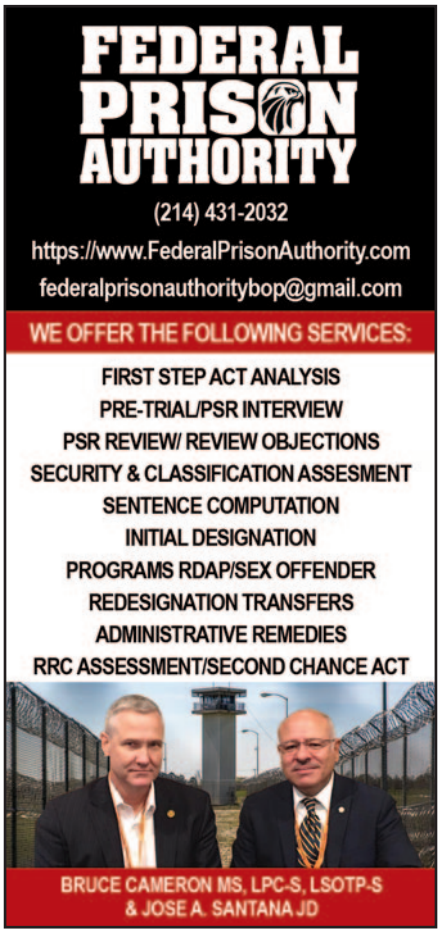
Origin determination is a fire investigator's "core competency." If one cannot determine where the fire started, it is unlikely one will be able to determine why, yet repeated experiments designed to assess fire investigators' ability to correctly determine the origin have so far not yielded any validation of this skill. Origin is defined as the exact physical location within the area of origin where a heat source and the fuel interact, resulting in a fire or explosion. So how good are fire investigators at actually determining where a fire started?

For many years, the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) conducted an exercise at the beginning of its advanced origin and cause school, which it presented at the Federal Law Enforcement Training Center in Brunswick, Georgia. Fire investigators from around the country who had been flown into Brunswick at government expense were presented with a fire scene of known origin. They were asked on the first day of the course to write down where they thought the fire started and submit their results anonymously. Over the years, fire investigators got no more than 8 to 10% of the answers correct.[19]

In 2005, three ATF certified fire investigators decided to take this exercise to the general fire investigation community. They ran their experiment at a fire investigation seminar in Las Vegas. They set up two rooms like bedrooms and ignited the fire. They let them burn for two minutes beyond flashover.[20] Then they invited the attendees to choose the *quadrant* where the fire originated. Relying on nothing but the interpretation of fire patterns, more than 90% of the participants chose the wrong quadrant. The experiment was repeated in the second room and the same results were obtained. In each case, only three of 53 investigators correctly identified the quadrant of origin.

Agent Steve Carman, one of the architects of the experiment, began teaching the fire investigators who would listen that perhaps they were not doing it right. He concluded that "the old days of finding the origin by using the lowest and deepest char are over," but there was quite a bit of pushback.

In 2007, the ATF conducted a similar exercise in Oklahoma City. In this case, the ATF set three fires. One fire burned for 30 seconds beyond flashover. The second fire burned for 70 seconds beyond flashover, and the third fire burned for three minutes beyond flashover. Again, participants at a fire investigation semi-



nar were asked to select the quadrant of origin. There were 70 attendees. For the 30-second fire, all 70 ventured a guess as to the quadrant of origin, and 84% got it right. For the fire that burned for 70 seconds beyond flashover, six investigators called the origin undetermined. Of the 64 who ventured a guess, 69% got it right. For the fire that burned for three minutes beyond flashover (and most fire investigators rarely see fires that burned for that brief a period of time) only 25% correctly identified the quadrant of origin. Twenty-five percent is no better than random chance.

In 2012, Tinsley and Gorbett published "Fire Investigation Origin Determination Survey." In that study, 587 self-selected fire investigators, working independently, viewed photos and data from a fire that burned for only one minute after flashover. The error rate was 22 to 26%.[21]

As of 2022, *there has not been a single experiment conducted* where fire investigators were able to demonstrate their ability to determine the origin correctly if the fire burned more than three minutes.

The length of burning should always be a question that an expert proposing to opine about the origin is asked, and if he is picking an origin out of a fully involved compartment that burned for more than three minutes, counsel should challenge the validity of that finding.

Expert Assistance Is Essential

Unless they specialize in fire cases, most attorneys will only encounter one or two arson cases in a career. Thus, it is necessary to engage an expert in almost all cases. Recent court cases have established that proceeding without an expert is *per se* ineffective, and so getting funding from the court is not the difficult problem that it once was. Two cases to cite if the court is reluctant to fund an expert are *Dugas v. Coplan* from the First Circuit and *Richey v. Bradshaw* from the Sixth Circuit.

In the *Dugas* case, the appeals court found that counsel had been ineffective even though he toured the scene with his client, did some reading, and took the depositions of the State's experts. They found that it fell below the constitutional requirement for effective assistance that counsel failed to consult with an expert, even though he planned to challenge the State's experts regarding their determination that the fire was intentionally set and not accidental.[22]

The *Richey* case is even more instructive. Richey's attorney hired an expert, but one who was determined by the Sixth Circuit to be incompetent. They held that effective assistance required hiring not just any expert but a *competent* expert.[23] In the past, I was often asked to provide services *pro bono* because counsel could not afford to hire an expert. That has not generally been the case since 2010. In fact, even in cases where the arson is obvious, I am retained to review the data because counsel feels that having the scientific case looked at by an expert is a matter of due diligence. Even in the obvious cases, questioning of the expert's qualifications has resulted in benefits to the accused. Qualifications challenges have also resulted in substantial reductions in the settlement value of civil cases.[24]

Conclusion

Fire litigators need to know that fire investigation, as a profession, has changed dramatically over the past three decades and it continues to advance today. Challenges to experts are becoming more common and generally expected. Counsel should question the qualifications of experts because the fire investigation profession contains a substantial cadre of unqualified investigators. Despite the confidence of many experts, fire investigation is very difficult, and the error rate is unknown, but potentially very high. Many of the people practicing fire investigation do not meet the qualifications for fire investigator set forth in NFPA 1033, and even those who survive a test of their knowledge may have engaged in questionable methodology. If the defense team does not vet its own expert, opposing counsel surely will.

Methodology should follow NFPA 921 and if it does not, investigators need to be able to explain why not.

The core competency of fire investigators, origin determination, has not been demonstrated to be valid, even though courts are unlikely to exclude it on that basis.

Because of recent court decisions, getting funding for an expert is not as difficult as it once was. The judge should understand that refusing to supply funding is the same thing as causing defense counsel to render ineffective assistance.

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Notes

1. Committee on Identifying the Needs of the Forensic Science Community (2009), *Strengthening Forensic Science in the United States: A Path Forward*, at S-6, available at http://www.nap.edu/catalog/12589.html.

2. *Id.* at 5-35.

3. A. Ahrens & B. Evarts, NFPA, *Fire Loss in the United States in 2020* (2021), available at https://www.nfpa.org/News-and-Research/Data-research-and-tools/US-Fire-Problem/Fire-loss-in-the-United-States.

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5. NFPA 921, *Guide for Fire and Explosion Investigations,* NFPA (1992, 1995, 1998).

6. NFPA 921, *Guide for Fire and Explosion Investigations,* NFPA (2001, 2005, 2008, 2011, 2014, 2017, 2021). NFPA 921 defines *fire science* as "The body of knowledge concerning the study of fire and related subjects (such as combustion, flame, products of combustion, heat release, heat transfer, fire and explosion chemistry, fire and explosion dynamics, thermodynamics, kinetics, fluid mechanics, fire safety) and their interaction with people, structures, and the environment."

7. J. Lentini, *The Persistence of Floor Coating Solvents*, 46(6) J. Forensic Sci. 1470-1473 (2001), available at https://app.box.com/file/907121373350.

8. J. Lentini, *Fire Investigation: Historical Perspective and Recent Developments*, Forensic Sci. Rev. 37-44 (Jan. 2019), available at https://app.box.com/file/907119536436.

9. Technical Working Group on Fire and Arson Scene Investigation, *Fire and Arson Scene Evidence: A Guide for Public Safety Personnel* (NJC I 81584) (2000), National Institute of Justice: https://nij.ojp.gov/library/publications/fire-and-arson-scene-evidence-guide-public-safety-personnel.

10. NFPA 921, *Guide for Fire and Explosion Investigations,* § 19.6.5 NFPA (2021).

11. OSAC Technical Guidance Document 005, *Strengthening Fire and Explosion Investigation in the United States: A Strategic Vision for Moving Forward* (2021), https://doi.org/10.29325/OSAC.TG.0005.

12. *State of Georgia v. Weldon Wayne Carr,* Case No. Z-58558-A (Superior Court of Fulton County 1994); *see also State of Georgia v. Weldon Wayne Carr,* 482 S.E.2d 314 (1997), available at https://law.justia.com/cases/georgia/supreme-court/1997/s96a1626-1.html.

13. *Michigan Millers Mutual Insurance Company v. Janelle R. Benfield,* 140 F.3d 915 (11th Cir. 1998), available at https://caselaw.findlaw.com/us-11th-circuit/1396573.html.

14. *Kumho Tire Co., Ltd., et al. v. Carmichael et al.* (1999), available at https://caselaw.findlaw.com/us-supreme-court/526/137.html.

15. P.W. Burke, *Amicus Curiae* brief filed on behalf of the International Association of Arson Investigators, in *Michigan Millers Mutual Insurance Company v. Janelle R. Benfield* (1997).

16. *Weisgram v. Marley Co.*, 169 F.3d 514, 520-21 (8th Cir. 1999), https://casetext.com/case/weisgram-v-marley-company.

17. P. Trexler, *Prosecution Expert Rejects Short as Cause*, AKRON BEACON J., February 8, 2002.

18. *Truck Insurance Exchange v. Magnetek*, 360 F.3d 1206 (10th Cir. 2004), available at https://casetext.com/case/truck-ins-exchange-v-magnetek-inc.

19. S. Carman, *Improving the Understanding of Post-Flashover Fire Behavior*, in Proceedings of the 3rd International Symposium on Fire Investigations Science and Technology (ISFI) (2008), available at http://carmanfireinvestigations.com/publications.

20. NFPA 921 defines flashover as "[a] transition phase in the development of a compartment fire in which surfaces exposed to thermal radiation reach ignition temperature more or less simultaneously and fire spreads rapidly throughout the space, resulting in full room involvement or total involvement of the compartment or enclosed space." Simply put, the fire changes from "a fire in a room" to "a room on fire." A two-minute mp4 movie showing a typical flashover can be downloaded from box.com using this link: https://app.box.com/s/jj0b23n0mfnw79xvdoeeifsbkrnltksp.

21. A. Tinsely & G. Gorbett, *Fire Investigation Origin Determination Survey*, presented at the Proceedings of the 5th International Symposium on Fire Investigation Science and Technology 53-68 (Oct. 15-17, 2012), available at https://forensicfireinstitute.com/wp-content/uploads/2018/07/fire-investigation-origin-determination-survey-.pdf.

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About the Author

John J. Lentini, CFI has been investigating fires for 48 years. He was a charter member of the NIST/OSAC Subcommittee on Fire and Explosion Investigations. His book, *Scientific Protocols for Fire Investigation,* is in its Third Edition. He is the principal investigator at Scientific Fire Analysis, LLC.

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