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Case Study: Cameron Todd Willingham

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Cameron Todd Willingham

Slow and painful has been man's progress from magic to law... Sometimes, with the benefit of insight gained over time, we learn that what was once regarded as truth is myth, and what was once accepted as science is superstition.

Han Tak Lee v. Franklin Tennis (2014)

INTRODUCTION

Cameron Todd Willingham was executed for the arson deaths of his three infant daughters. Many believe his execution should never have taken place, and as fire science advances, it is becoming clearer that Texas executed an innocent man. Willingham's case is one of the most scrutinized arson investigation cases in the US due to the serious questions raised regarding the validity of the methodology employed in the investigation and the potential that the fire was a tragic accident, and Willingham was executed for a crime that never was (Grann, 2009; Innocence Project, 2006). The fire and arson investigation evidence played a key role in Willingham's conviction and has subsequently been the subject of independent investigations by journalists (Grann, 2009; Mills and Possley, 2004), the Innocence Project (2006), and the Texas Forensic Science Commission (2011). Conclusions from these parties concurred that the claims made by the Deputy Fire Marshal and Assistant Fire Chief and relied upon by the jury were unsupported by the evidence and that their testimonies overstepped the purview of their expertise. Though Willingham was not officially exonerated by a court of law, in 2012, former Justice Charlie Baird, who led an inquiry into the state's activity in the case

regarding recanted testimony by a jailhouse informant, concluded that Willingham was wrongly executed (McLaughlin, 2012; Baird, unpublished opinion).

Willingham's case exemplifies the use of outdated methods in arson investigation and how conclusions based on these methods can form the foundation of a wrongful conviction. It highlights the dangers of confirmation bias, the consequences of investigators drawing conclusions that are unsupported by evidence and research, and the lack of general scrutiny paid by defense counsel, the prosecution, judges, and appellate justices. More research is needed to improve the empirical basis of the methodologies used in fire and arson investigation, and greater resources and effort should be afforded educational programs for legal practitioners who encounter this evidence in court.

THE FIRE

On December 23, 1991, in Corsicana, Texas, police and firefighters arrived onsite to put out a fire that had engulfed a one-story house. The resident of the house, Cameron Todd Willingham, was home caring for his 2-year-old daughter, Amber, and 1-year-old twin girls, Karmon and Kameron. His wife was Christmas shopping. Willingham told police that he was asleep when the fire started, and he was awoken by thick smoke in the room. He exited the house to look for help, instructed his neighbor to dial 911, and reentered the home to look for his daughters. He was unable to find the girls, and firefighters restrained him from reentering the house due to the intensity of the fire. Willingham's eldest daughter was found in the master bedroom, and the twins were found in the children's room, having suffered severe burns. Medical examiners later concluded the children died from smoke inhalation and that Willingham had suffered minor burns on his feet and had evidence of smoke in his lungs.

THE FIRE INVESTIGATION

The Assistant Fire Chief of Corsicana, Douglas Fogg, arrived first on site and conducted the initial investigation. He had over 20 years of experience as a firefighter and was a certified fire investigator (Grann, 2009). Deputy Fire Marshal Manuel Vasquez from the State Fire Marshal's Office joined the investigation a few days later. Vasquez had investigated over 1200 fires and was highly experienced in arson investigation (Grann, 2009). Vasquez and Fogg examined all rooms in the house and its perimeter and collected samples for gas chromatography and mass spectrometry (GC-MS) testing for traces of accelerants. Their investigation included several avenues of inquiry that were not restricted to the examination of the fire site. They interviewed Willingham and his wife on several occasions as well as eyewitnesses to the fire and Willingham's friends and neighbors. They accessed medical reports from the hospital that treated Willingham for injuries sustained in the fire and the coroner's reports of the death of the three children. They also worked closely with the Houston Police, who shared with them Willingham's criminal record of truancy, driving under the influence, shoplifting, and a past history of domestic abuse.

During their site investigations, they noted burn patterns throughout the house and looked for natural explanations of how, why, and where the fire might have started, including claims of faulty electrical wiring. Between them, they identified over 20 burn patterns that they believed were evidence that the fire was intentionally set. They also collected over a dozen samples throughout the premises to test for the presence of accelerants through GC–MS. The results came back negative for all of the samples, with the exception of one sample on the front porch where the family kept the home barbecue and its gas tank. The investigators concluded that the fire was intentionally set; it was arson.

THE TRIAL

Cameron Todd Willingham was charged with three counts of murder and was eligible for the death penalty. The state offered him a life sentence if he pled guilty; however, Willingham refused the offer. The trial took place over 2 days, and the prosecution's case included eyewitness testimony about the events on the day of the fire and Willingham's behavior during and after the fire, a positive chemical test of the sample retrieved from the porch outside the house, the testimony of a jailhouse informant who testified that Willingham confessed to having set the fire to intentionally kill his children, and the expert testimony of fire investigators, Fogg and Vasquez.

Two months after the fire that killed Willingham's daughters, the US National Fire Protection Association (NFPA) published a guide for fire investigators (NFPA 921) that, if followed, would have debunked the evidence against Willingham (Mills and Possley, 2004). Fogg and Vasquez did not rely on the NFPA 921 (Mills and Possley, 2004). They identified several indicators that they believed were the results of arson, including irregular patterns on the floors that they believed were puddle configurations or pour patterns caused by the use of accelerants. These pour patterns were found under the children's beds and in doorways, strengthening the State's contention that Willingham intended to block escape routes and kill his children. They testified that multiple V patterns on the walls caused by smoke and low burn patterns on the bedroom walls indicated multiple ignition sites that would not be present in an accidental fire. They also testified that charred wood on the base of a screen door, alligating of floor boards, melted bed springs, and spider web patterns on glass windows, known as "crazed" glass, indicated the fire burned hotter than would a naturally occurring fire (Hurst, 2004). All of these characteristics were said to be proof that the fire that killed Willingham's three children was intentionally set. After 90 min of deliberation, the jury found Willingham guilty on all counts, and the judge sentenced him to death.

POSTCONVICTION

Willingham appealed his conviction nine times before the Texas State Court of Appeals on different issues; however, none challenged the validity of the expert testimony by the fire investigators at trial (Dioso-Villa, 2013). He filed a habeas

corpus petition that the US District Court denied. It too did not take issue with the contested fire investigation; this may be blamed on the relative complexities inherent when scientific expert evidence is challenged postconviction (Wolf, 2008). In a final step, Willingham sought clemency from the Governor of Texas and requested a 90-day stay of execution to investigate the potentially erroneous fire and arson investigation evidence in the case. To accompany the petition, his lawyer filed a report written by fire and explosives expert, Gerald Hurst, who had the opportunity to review the evidence in the case and identified errors in Fogg and Vasquez's testimonies and conclusions that the fire was intentionally set (Hurst, 2004). Hurst reviewed each of Fogg and Vasquez's identified indicators of arson and contested their explanations, concluding that the patterns the investigators identified are often present in naturally occurring fires. Hurst also stressed that the presence of an accelerant could only be established by chromatographic analysis in a laboratory; recall that the only area that tested positive for an accelerant was the front porch where the family kept their barbeque. Thus, the prosecutor's theory that there were multiple areas of origin marked by pour patterns proving Willingham used an accelerant was patently false. Regardless of compelling evidence that the fire was not arson, Governor Rick Perry and the Texas Board of Pardons and Paroles ultimately declined the petition for a stay of execution, and Willingham was executed by lethal injection as scheduled after having served 12 years in prison.

FIRE AND ARSON INVESTIGATION

This case highlights key issues that arise when fire and arson investigation testimony is admitted into court as expert evidence. As a reconstruction science that includes interpretive analysis, it is unlike comparative analysis (such as fingerprint examination or tool mark comparisons) or empirical analysis (such as chemical analysis, drug identification, forensic DNA testing, or gunshot residue or explosive residue analysis), and distinct from strict observations (such as eyewitness accounts) (Porter, 2011). Unlike its forensic counterparts, fire investigators must determine whether a crime has taken place at all. There are challenges to this, considering that training may vary across jurisdictions and by investigator, as may the resources and tools available to the investigator, independent of which tools he or she may decide to use during the course of each investigation (Dioso-Villa, 2013; May, 2011; Plummer and Syed, 2012).

TRAINING: EXPERIENCE-BASED EXPERTISE

According to Willingham's trial transcripts, Douglas Fogg, the Assistant Fire Chief for the Corsicana Fire Department, had been a part of the fire department for 22 years; little else is revealed or discussed regarding his qualifications and expertise, though he was admitted as an expert witness and permitted to give evidence at trial. Deputy

State Fire Marshall Manuel Vasquez testified as having been a certified peace officer for 15 years through his previous work in the armed forces, and a certified fire investigator for 15 years. He was a member of Texas Law Enforcement Intelligence Association and the North Texas Fire Investigators Association. He testified that he had investigated between 1200 and 1500 fires as a certified fire investigator and that “with the exception of a few, most all of them” were arsons ([Statement of Facts, 1992](#), p. 228). At the time of the trial, he had testified as an expert witness in over 25 trials, and in all cases, with the exception of a few civil cases, he testified on behalf of the prosecution.

As the variations in the two fire investigators’ training and experience in Willingham’s case demonstrates, there is no current requirement that fire investigators have specific certifications in order to testify as an expert witness, nor is there any formal training or specialized courses that a person must take before conducting fire investigations ([Dioso-Villa, 2013](#); [Lentini, 2006](#)). Given the consideration of varied training, experience, and resources, two fire investigators may arrive at different conclusions about the cause(s) or origin(s) of the same fire, or they may arrive at the same conclusions using very different investigative techniques.

TOOLKIT: OUTDATED ARSON INDICATORS AND THIRD-PARTY EVIDENCE

As discussed in depth below, fire investigators have repeatedly relied upon heuristics passed down from mentor to apprentice to determine whether a fire was intentionally or accidentally set. Some of these heuristics include what became known among fire investigators as arson indicators and remained undisputed until the 1980s ([Lentini, 2006](#)). Vasquez, Fogg, and the fire investigation community in general believed that arson fires produced burn patterns distinguishable from naturally set fires based on the widely accepted premise that fires that used an accelerant burned hotter and faster than a natural burning fire. In the Willingham case, Fogg and Vasquez identified over 20 arson indicators, such as melted metal (since metal melts at such a high temperature not reached in a natural fire), alligatoring (alligator patterns on wooden floor boards produced by an accelerant), and crazed glass (spider web patterns on windows believed to have been produced by extreme temperatures in a room) ([Innocence Project, 2006](#)). Although by the time of Willingham’s trial in the early 1990s, new evidence suggested that natural fires that occurred in small, enclosed spaces could produce artifacts consistent with arson indicators if the room reached flashover ([Dioso-Villa, 2013](#); [Lentini et al., 1993](#); [May, 2011](#); [Plummer and Syed, 2012](#)), Fogg and Vasquez were not aware that what they observed in the aftermath of the Willingham fire was the natural consequence of flashover. In Willingham’s small house, flashover occurred when a hot gas layer built up to the ceiling with no chance of escaping causing the combustible material in the room to ignite at the same time, thus causing artifacts, Fogg and Vasquez interpreted, as indicators of arson.

The Innocence Project, investigative journalists, the courts, a special investigative task force, and the media have questioned Willingham's conviction and execution, given the weight that the jury must have attributed to the fire investigators' expert testimony that relied so heavily on "arson indicators." In addition to arson indicators that lack scientific rigor, fire investigators have a host of other tools available to them to assist with determining the origin and cause of fires. In Willingham's case, Fogg and Vasquez accessed medical records and coroners' reports, interviewed eyewitnesses and character witnesses, interviewed the suspect, read fire reports, conducted site inspections, collected samples for GC-MS testing, and had access to Willingham's criminal record. These reports and the collection of investigative facts are part of how a fire investigator may reach his or her conclusion about the cause and origin of the fire.

Unfortunately, as the National Academy of Sciences' report on the evaluation of the forensic sciences points out, fire and arson investigation, like other forensic disciplines, lacks the necessary empirical rigor to make the claims that fire investigators make in court. In addition, they recommend that their training, reporting, and testimony should attempt to be standardized to address these limitations.

By contrast [to the analysis of explosions], much 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 (e.g., "alligatoring" of wood, specific char patterns) have been shown not to be true. Experiments should be designed to put arson investigations on a more solid scientific footing.

(National Research Council (2009), pp. 5-34 to 5-35)

THE IMPACT OF EXTRA-LEGAL FACTORS

The key features of fire investigation can pose problems for judges and jurors as they interpret the testimony and evidence. Fire investigators reach conclusions that are based on physical evidence found at the fire site and may also incorporate investigative facts about the crime or defendant in reaching a determination of arson. In Willingham's case, Vasquez testified that his conclusion was based in part on external factors independent of the physical evidence, including his experience, training, and interviews with witnesses and the defendant. This holistic view is not uncommon in the forensic sciences, given the argument that forensic examiners may benefit from knowing case facts in order to select the analyses required and to conduct the analyses accurately (Thompson, 2011). In the case of fire investigation, this raises the question of whether the fire investigator has any reason at all to investigate such issues as the defendant's character or criminal history. That is, is this information required in order to make a scientific determination about how a fire started? If a holistic approach is desired, then

it should be restricted to only evidence that touches directly on the physical aspects of fire science. Any further inquiry by fire investigators into the character of the defendant is so far removed from the fire investigator's role that it runs the increased risk and likelihood of bias and the misinterpretation of the physical evidence.

CONFIRMATION BIAS

Confirmation bias can occur when an analyst knowingly or unknowingly seeks or interprets information in a way that supports their beliefs, hypotheses, and expectations (Nickerson, 1998). For example, investigative facts, such as knowing that the suspect confessed or that the suspect has a criminal record of similar offenses, may affect how an analyst interprets findings (Dror et al., 2006). In Willingham's case, we can draw inferences that suggest confirmation bias led to his conviction. From Vasquez's testimony at trial, he appeared to see Willingham as a physically abusive husband who had reacted to the deaths of his children in unexpected ways. These impressions about Willingham's character, informed by eyewitness statements and criminal record, certainly could have influenced the way in which Vasquez interpreted the physical evidence in his investigations. The likelihood of bias increases when analyses are made and conclusions are drawn based on "art" and not on empirical analysis. Thus, it is telling that Vasquez believes, "the fire tells a story" and he is just the fire's "interpreter," and Fogg believes, "the fire talks to you...[t]he structure talks to you...[y]ou call that years of experience" (Mills and Possley, 2004).

THE ULTIMATE ISSUE

When forensic examiners testify at trial, there is a danger that they may make claims that extend beyond the science, methodology, or their expertise, or they may exaggerate the value of the evidence (National Research Council, 2009). This is especially dangerous for fire investigators since their task is to determine the cause and origin of the fire, which can broach the ultimate issue of the case: whether there was a crime at all and whether the defendant intended to commit the crime.

In Willingham's case, Vasquez testified that he believed that the fire was intentionally set. He also testified that he believed, based on the investigation and his experience, that Willingham started the fire with the intent to kill his three infants (Dioso-Villa, 2013; Grann, 2009). In general, there are no scientific methods that can support such specific claims of a person's intent. However, in cases where arson is suspected, it is natural that fire investigators may think that they have found absolute proof of intent to kill, such as here, where the expert testified a specific pattern proves the defendant poured an accelerant under his child's bed as well as in doorways in order to block the child's means of escape. Endowing any expert with the faculty to prove both that a crime was committed and that the suspect intended the death of the victim is inherently dangerous, and the enormity of this faculty should require that experts be vetted to a much greater extent.

CONCLUSION

Willingham was convicted and sentenced to death in 1992. He had nine unsuccessful appeals, an unsuccessful habeas corpus petition, his clemency petition was rejected, and he served 12 years in prison before being executed in 2004. Since then, the practice of relying on arson indicators as a method of fire investigation has been contested and challenged within the fire investigation community and in the general media. The Innocence Project submitted a petition that the Texas Forensic Science Commission reinvestigate the case because the investigators relied on outdated and disproven arson indicators in their investigations. Although the case fell out of the Commission's jurisdiction, likely due to political considerations, the Commission nonetheless issued a report that stated that the methods used in the investigation were flawed (Texas Forensic Science Commission, 2011). Willingham's conviction and execution have illustrated the dangers of admitting unsound arson evidence into court and the blind reliance on experts who do not have a science-based foundation for their beliefs. To address these concerns requires considerable attention to the training and vetting of experts and greater understanding of the science of fire and arson by legal practitioners involved in fire-related litigation.

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Confronting Inaccuracy in Fire Cause Determinations

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With a few exceptions, forensic science disciplines lag behind many other sciences. This is largely because the underpinnings of the forensic sciences do not lie in academia or industry, but were developed as a response to a need for information by the justice system.

As with any historical science, it is difficult (maybe impossible) to accurately measure the rate of error of many forensic science methodologies, and among the forensic disciplines, fire investigation probably presents one of the more difficult challenges. In the absence of a video of the actual fire in progress, it is difficult to determine whether a fire investigator’s conclusions are accurate or wide of the mark. It is possible, however, to state with some confidence that while the situation is improving, there are still many errors that occur.

Fire investigation is different from many sciences, and even from many forensic sciences, by virtue of the fact that its practitioners largely lack any formal scientific education. Yet every day, we ask them to make sophisticated decisions about chemistry, heat transfer, fluid dynamics, and electricity. Fire investigators are generally drawn from the ranks of the police and fire services. Training historically has been

done “on the job” with an experienced mentor passing on his belief system to new recruits. Thus, fire investigation suffers from two major challenges to its reliability: unqualified practitioners and invalid methodology.

LACK OF QUALIFICATIONS

In Europe, there is much variation in the quality of fire cause investigations and practitioner standards (Tedim et al., 2015). In England, in 2007, they created a regulatory entity to set and maintain standards for forensic scientists, and appointed a Forensic Regulator. Fire scene investigators are accredited and must conform to standards set forth in International Standards Organization Section 17020. In Norway and the Netherlands, neutral experts are appointed by the court (Stridbeck et al., 2013; Brants, 2011). In Canada, fire scene investigation training is not standardized. Some provincial Offices of the Fire Marshal have adopted NFPA standards (Wright and Singer, 2014). Marshals regulate training of fire investigators who may qualify as expert witnesses (Id.; Office of the Fire Marshal and Fire Departments). In 1994, the Supreme Court of Canada established that the admission of expert testimony depends on its relevance and necessity in assisting the trier of fact, the absence of any exclusionary rule, and a properly qualified expert (R. v Mohan, 1994). The “qualified expert” must have “acquired special or peculiar knowledge through study or experience in respect of the matters on which he or she undertakes to testify” (R. v Mohan, 1994).

Federal Rule 702 and most state rules regarding experts begin with the phrase, “an expert who is qualified...” Until 2010, however, who is qualified was a decision left up to the individual and almost always ratified by the judge if the individual had previously been qualified as an expert witness. This is changing due to the changes in the *Standard for Professional Qualifications for Fire Investigator*, known as NFPA 1033.

NFPA 1033 sets forth an objective list of subjects that the investigator is required to know at a level beyond high school. The document reads as follows:

1.3.7* The investigator shall have and maintain at a minimum an up-to-date basic knowledge of the following topics beyond the high school level:

1. fire science
2. fire chemistry
3. thermodynamics
4. thermometry
5. fire dynamics
6. explosion dynamics
7. computer fire modeling
8. fire investigation
9. fire analysis
10. fire investigation methodology
11. fire investigation technology
12. hazardous materials

13. failure analysis and analytical tools
14. fire protection systems
15. evidence documentation, collection, and preservation
16. electricity and electrical systems (NFPA 1033, 2014)

This list of required knowledge provides the courts with guidance on who is qualified and who is not. While challenges to experts have typically been challenges to methodology, it is now becoming common for fire investigators to be required to endure a “quiz,” testing their knowledge of the subjects listed above. At the very least, someone who holds himself out as an expert should be able to define the subjects.

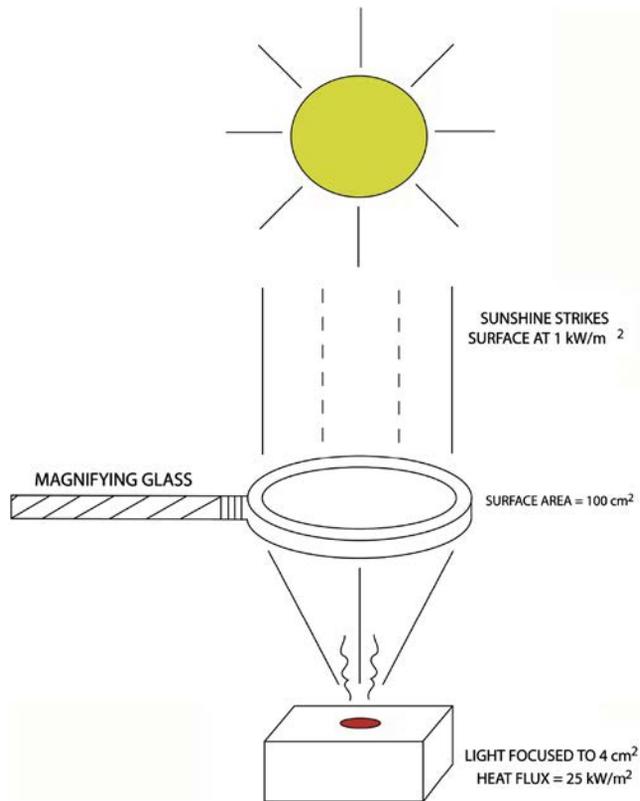
NFPA 921, *Guide for Fire and Explosion Investigations*, described as follows, defines **Fire science**, the first item on the list, as “the body of knowledge concerning the study of fire and related subjects (such as combustion, flame, products of combustion, heat release, heat transfer, fire and explosion chemistry, fire and explosion dynamics, thermodynamics, kinetics, fluid mechanics, fire safety) and their interaction with people, structures, and the environment” (NFPA 921, 2014).

Fire is a rapid oxidation process, an exothermic (energy releasing) chemical reaction involving the generation of heat and light in various quantities. Heat and light are forms of energy, and it can be argued that a fire investigator who does not know the basic units of energy is really not qualified to render expert opinions the behavior of fire. The very basic knowledge in the following paragraphs is something that a fire expert should know in his or her bones, but sadly, many purported experts do not possess this knowledge (*see the deposition excerpts in the sidebar*).

Energy. Energy is a property of matter that is manifest as an ability to perform work, either by moving over a distance or by transferring heat. Energy can be changed in form (e.g., from chemical to mechanical energy) or transferred to other matter, but it can neither be created nor destroyed. Energy is measured in joules (J) or calories (cal) or British Thermal Units (Btu). A joule is the heat produced when 1 A is passed through a resistance of 1 Ω for 1 s, or it is the work required to move over a distance of 1 m against a force of 1 N. A calorie is the amount of energy required to raise the temperature of 1 g of water by 1°C (from 14°C to 15°C); a calorie is equal to 4.184 J. A Btu is the quantity of heat required to raise the temperature of one pound of water 1°F at a pressure of 1 atm and a temperature of 60°F; a British thermal unit is equal to 1055 J, and 252.15 calories.

Power. Power is a property of a process such as fire that describes energy released *per unit time*. The same amount of energy is required to carry a load up a flight of stairs whether the person carrying it walks or runs, but more power is needed for running because the work is done in a shorter amount of time. Raising the temperature of a volume of water requires the same amount of energy whether the temperature increase takes place in 10 s or in 10 min. Raising the temperature more rapidly requires more power because the energy is transferred more rapidly. Power is measured in joules per second (J/s) or watts (W).

Heat flux. Heat flux is a property of a process such as fire that describes the amount of power *per unit area*. A kilowatt spread over one square meter is approximately equal to the radiant heat flux outdoors on a sunny day. If that same kilowatt is concentrated

**FIGURE 3.1**

Using a magnifying glass to concentrate the radiant heat flux from the sun.

by a factor of 25 using a magnifying glass, there will be sufficient energy transferred to that area to cause ignition of combustibles (See Fig. 3.1).

Heat flux is measured in kW/m^2 or W/cm^2 . There are 10,000 square centimeters in a square meter. The value for the smaller area is important in evaluating the *competence* of a proposed ignition source. The critical radiant heat flux necessary to cause ignition is $25\text{--}30 \text{ kW/m}^2$, which might seem like a lot of power, but most fires start small, and it only takes $2.5\text{--}3 \text{ W}$ to ignite a combustible fuel if the energy is concentrated in an area smaller than a square centimeter.

Fire chemistry covers many subjects, but one would have to think that knowing the formula for the combustion of hydrogen, the simplest of all combustion reactions, would be something even a novice fire investigator would learn ($2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$). The simplest of all *hydrocarbon* combustion reactions is the combustion of methane, the main ingredient of natural gas ($\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$). One volume of natural gas requires two volumes of oxygen (10 volumes of air) for complete combustion.

What follows are examples of testimony of fire investigation “experts” who could arguably be prevented from testifying because of their failure to know the basics about how fire behaves.

This expert is from testimony given by an electrical engineer (PE) who investigates fires (April 12, 2012).

Q. How is radiant heat flux measured?

A. Oh, I can’t remember the actual units but I could look it up. I just don’t remember what the actual units are because it’s not a common...

Q. Do you know what the generally accepted value of radiant heat flux that will result in a flashover is?

A. No.

Q. If you were outside like today on a cloudless day at noon, what is the radiant heat flux that a square meter of the earth’s surface is receiving from the sun?

A. I don’t know.

Many of the other subjects listed in NFPA 1033 are duplicative, but it is not unreasonable to expect a fire investigator who proposes the “elimination of all accidental causes” to have sufficient knowledge of electrical systems to wire a house and to know enough about fire protection systems to understand whether they did or did not function properly.

This testimony was offered by a certified fire investigator (CFI) with over 30 years of experience. He was working with the previous investigator. He “determined” there were seven areas of origin, all of which were contiguous, in a warehouse fire that burned for at least 6 h.

Q. What is radiant heat flux?

A. That is a measurement of the heat being radiating such as the sun is radiant heat.

Q. And how is it measured?

A. The sun is measured in temperatures, in degrees, both Fahrenheit and Celsius.

Q. Is there a generally accepted value of radiant heat flux that will result in a flashover?

A. Yes.

Q. Do you know what that is?

A. What, flashover?

Q. What the value is?

A. No.

Q. Do you know what the chemical symbol for hydrogen is?

A. No, but I know where to look it up.

Q. What about a chemical formula for hydrogen gas, do you know what that symbol is?

A. No.

Q. Or the chemical symbol for oxygen?

A. I know where to look them all up.

Q. And likewise, do you know what the chemical symbol for oxygen gas is?

A. No, but I know where to look them up.

Q. What is the chemical reaction for the combustion of hydrogen?

A. I don’t recall.

“Knowing where to look it up” is not what the writers of NFPA 1033 had in mind when they prescribed a knowledge of fire chemistry, but that is the fallback answer of many investigators.

This expert was the investigator (CFI) in a contested cooking fire case (October 24, 2013).

Q. What are the basic units of energy?

A. Basic units of energy. Power, and I forgot what the other one was right now. But I can look that up for you also.

Q. What are the basic units of power?

A. Basic units of power? I would have to look that up for you also.

Q. Well, what is a watt? Define it.

A. Define a watt. I'd have to look it up for you.

Challenges to experts' qualifications will often take place well before a court is asked to rule on them, and, in fact, when one party's expert is unable to answer simple questions about fire and energy, the result is frequently that the case settles because counsel does not feel comfortable with the expert anymore. The sidebar contains actual excerpts from transcripts of certified fire investigators with many years of experience and shows that being certified is not the same as being qualified. Challenges based on a lack of qualifications are becoming more common. The author once witnessed a successful challenge of a proposed expert who was unable to describe the combustion of hydrogen. Without being asked, the Judge interrupted the proceedings and stated, "I'm sorry. If you don't know H₂O, you will not be rendering opinion testimony in my courtroom."

This testimony was given by a second investigator (CFI) who replaced the "expert" above (December 29, 2014).

Q. What are the basic units of energy?

A. Kilowatts, watts, horsepower, joules. I could go on.

Q. All of those are basic units of energy?

A. Yes.

Q. What are the basic units of power?

A. Those are your forces. I'd have to look that up for you.

Q. What is a "watt"?

A. Watt is a measurement of energy.

Q. What is it, though?

A. It's like a kilowatt. If I produce – it's named after Mr. Watt. Hang on. If you want me to tell you, I have to look it up for you, the exact definition.

What is the solution to the problem of underqualified or completely unqualified individuals holding themselves out as expert fire investigators? Unfortunately, short-term solutions are not available. The likelihood that an investigator, who has managed to obtain certification and make a comfortable living investigating fires for 30 years despite the lack of basic knowledge, will decide to learn some science is low. Investigators such as this can be discredited one case at a time, and eventually, that will reduce their workload as clients decide to hire someone who knows the basics. This is not going to change the overall picture, at least not quickly. As the great scientist Max Planck stated, "science advances one funeral at a time." To put it more kindly and apply it to the situation at hand, fire investigation advances one retirement at a time.

A certified fire and explosion investigator (CFEI), who claims a “magma [sic] cum laude” degree in fire science, opined that a propane-fired weed burner was used to set a fatal fire. The defendant was charged with capital murder on this basis (November 11, 2010).

- Q. Do you know how many BTUs are present in a typical cubic foot of propane?
A. Not at this time.
- Q. Do you know what the chemical formula for propane is?
A. I'm unsure at this time.
- Q. Can you write down the chemical equation that describes the burning of propane in air?
A. I'm unsure.
- Q. How many volumes of oxygen are required to burn a volume of propane?
A. Unsure.
- Q. Can you explain the difference between heat and temperature?
A. My opinion? Not “921” or any...
- Q. Yeah, your opinion.
A. Heat is the production of light and temperature from a product, and temperature is the natural measurement of that heat that's produced.
- Q. Okay. What's the basic unit of energy called?
A. I'm unsure at this time.
- Q. You ever heard of a joule?
A. I have.
- Q. What is it?
A. It's a measurement of energy or that's how – it has to do with electricity as well.
- Q. What are the basic units of power called?
A. AC and DC.
- Q. I'm sorry?
A. AC and DC.
- Q. Have you ever heard of a watt?
A. Yes, sir.
- Q. Would that be the correct answer?
A. More than likely.
- Q. What is a watt?
A. I mean I'm unsure. If you want me to look at a manual and give you these answers...
- Q. Do you know what a watt is?
A. No, sir.
- Q. Okay. How is the size of a fire measured?
A. I'm unsure at this time.
- Q. Okay. What is radiant heat flux?
A. I'm unsure at this time.

(The prosecutor moved for dismissal when she saw how her “star” witness was going to perform at trial.)

The long-term solution is to improve the quality of the applicant pool. This can only be accomplished by requiring a scientific background (as opposed to a fire extinguishing background or in addition to a fire extinguishing background) and paying individuals commensurate with that requirement. Faced with the prospect of a \$40,000 annual salary as a fire investigator or a \$100,000 annual salary as a fire protection engineer, most college graduates will opt for the latter. Until we as a society decide that fire investigation is a profession that requires a basic curriculum and that should command a decent salary, the problem of unqualified fire investigators will persist.

INVALID METHODOLOGY

Federal Rule 702 and most state rules devote more ink to methodology than to qualifications. The rule reads as follows:

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:

1. 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;
2. the testimony is based on sufficient facts or data;
3. the testimony is the product of reliable principles and methods; and
4. the expert has reliably applied the principles and methods to the facts of the case.

While all four subparagraphs provide avenues for challenge, it is the failure to meet the requirement that “the testimony is the product of reliable principles and methods” that is likely to result in inaccurate determinations of origin and cause.

The “methodological” failures in fire investigation do not often happen because of acts or omissions, but because of a failure to properly *interpret* postfire artifacts. While NFPA 921 does prescribe many desirable actions that should be accomplished by a fire investigator (methods), it is the interpretation of postfire artifacts, based on scientific research (principles), that is the most important part of the document. Most fire investigation errors can be attributed to failing to follow NFPA 921's extensive guidance on interpretation.

The first systematic study of potential problems with fire investigation methodology happened in 1977 when a team from the Aerospace Corporation, working for the US Department of Justice, conducted a survey of fire investigators and asked them what “indicators” they used to help them investigate fires and determine arson (Boudreau et al., 1977).

The indicators listed in the Justice Department report, all of which involved interpretation, included the following postfire artifacts:

Crazing of glass. Formation of irregular cracks in glass believed to be caused by rapid, intense heating, and thus an indicator of the use of a liquid accelerant (see Fig. 3.2).

Depth of char. The depth of burning of wood was used to estimate the duration of burning. It was widely believed that wood burned at a fixed rate. The deepest char must have been burning the longest.

Line of demarcation. On floors or rugs, a “puddle-shaped” line of demarcation was believed to indicate a liquid fire accelerant. In the cross-section of wood, a sharp, distinct line of demarcation indicates a rapid, intense fire (see Fig. 3.3).

Sagged furniture springs. Because of the heat required for furniture springs to collapse from their own weight (1150°F) and because of the insulating effect of the upholstery, sagged springs are believed to be possible only in either a fire originating inside the cushions (as from a cigarette rolling between the cushions) or an external fire intensified by a fire accelerant.

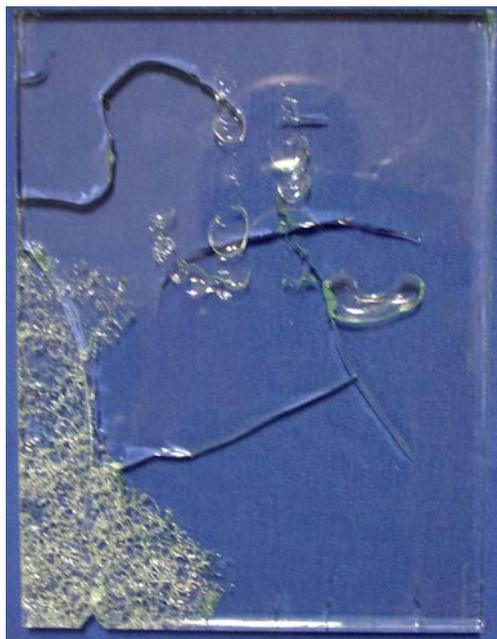


FIGURE 3.2

Crazed glass. Crazing only occurs in those areas to which water was applied. The author was able to write his initials using a wet cotton swab. Despite numerous textbooks that state the opposite, it is impossible to cause glass to craze by rapid heating. Crazed glass can only be caused by rapid cooling.



FIGURE 3.3

Sharp, continuous, irregular lines of demarcation between burned and unburned areas. The irregular patterns were caused by alternating exposure and protection of the underlying floor by the shrinking carpeting.

Spalling. This response by concrete to heating causes the surface of the concrete to chip or even explode violently. Brown stains around the spall were said to indicate the use of a fire accelerant (see Fig. 3.4).

In addition to those “indicators,” there were several other widely publicized and accepted means used to analyze a fire, including those listed here.

Fire load: Knowing the energy content (as opposed to the energy release rate) of the fuels in a structure was believed to allow an investigator to calculate the damage that a “normal” fire should produce in a given time frame. Some investigators referred to a “standard time temperature curve.”

Low burning and holes in the floor: Because heat rises, it was widely believed that burning on the floor, particularly under furniture, indicated an origin on the floor.

V-pattern angle: A V-pattern is caused by the interaction of a conical fire plume with a vertical surface, such as a wall. The angle of a V-pattern was believed to indicate the speed of the fire, with a wide V indicating a slow burning fire and a narrow V indicating a rapidly burning, and therefore accelerated fire.

Time and temperature: By estimating the speed of a fire or establishing the temperature achieved by a fire, it was believed that an investigator could determine whether it was accelerated or advanced at a “normal” rate.

All of these “indicators” are correctly categorized as “junk science.” What is amazing is that so much junk science has permeated fire investigation over the decades. The introduction and persistence of invalid indicators (all of which, by the way, were supposed to suggest an intentional fire) in fire investigation are an unfortunate part of the history of the discipline and a subject that many fire investigators do not like to think about. Some would like to keep these dirty little secrets locked away in a closet in the hope that people will gradually forget about them and they will not be a problem anymore. It is this failure to address a serious problem in



FIGURE 3.4

Concrete spalling on the ceiling of a parking garage under construction that caught fire.

the training and education of fire investigators that causes the myths to persist. The unfortunate consequence is that innocent lives are destroyed by well-meaning but ignorant investigators.

Just as in the study of Greek or Roman mythology, no single reason explains how or why a fire investigation myth develops. Certainly, no reason exists to believe that any investigator deliberately set out to promulgate something that he knew to be untrue. It is likely that most myths came about as a result of unwarranted generalizations. For example, an investigator might observe that in a garage fire, a pattern of spalling surrounds the remains of a gasoline container and makes an association of gasoline with spalling. The next time he sees spalled concrete, he infers that gasoline must have been involved.

Some myths arise because of intuitively obvious “deductions.” The notion that gasoline burns hotter than wood is appealing; as anyone who has ever started a wood fire knows, it is much easier to start it with liquid fuel, and certainly after a short time, a fire started with, for example, gasoline, is throwing off much more heat per unit time (kilowatts) than the fire burning wood only. Therefore, the flame temperature must be higher, right? Wrong! But even Paul Kirk, arguably one of the finest forensic scientists of his time, bought into this notion. In the first edition of his book *Fire Investigation* (1969), he described the utility of examining melted metals:

Whenever any residues of molten metal are present at the fire scene, they will reliably establish a minimum temperature for the point of their fusion in the fire. The investigator may use this fact to advantage in many instances, because of the differences in effective temperature between simple wood fires and those in which extraneous fuel, such as accelerant is present.

Kirk (1969)

To this day, investigators sometimes infer the presence of accelerants when they observe a melted aluminum threshold.

The authors of the 1977 study correctly pointed out that there was no scientific underpinning for **any** of these indicators and suggested that a series of experiments be conducted and a “handbook” for fire investigators be published. Unfortunately, the handbook was published in 1980 **without the experimental data!** Even more unfortunately, the *Handbook* was published by the US National Bureau of Standards (NBS, now known as NIST for National Institute of Standards and Technology), one of the most highly respected scientific and engineering bodies in the world (Brannigan et al., 1980). The indicators were often quoted in textbooks and thus became firmly embedded in the culture of fire investigation.

One by one, investigators and experimenters tested whether these indicators were, in fact, valid, and one by one, they were proven not to be (Lentini, 2012a,b). A large problem existed in the training methodology of the fire investigation profession. Well-meaning professional groups would conduct weekend seminars in which a structure or two was intentionally set on fire and then quickly put out. Fire investigators could then “learn how to recognize arson.” The difficulty with this type of test fire was that it

did not mimic real-world fires, which often burn for tens of minutes as fully involved fires. Throughout the 1980s, such exercises reinforced the belief that one could tell what a “flammable liquid pour pattern” looked like by visual observation alone.

Here, the investigator (CFI, CFEL) is testifying in a civil arson case based on a “pour pattern” at an alleged second area of origin (April 25, 2013).

Q. So the difference between heat and temperature.

A. Heat would be the, what is produced by something, and temperature would be what the air is, or what the surroundings are.

Q. What are the basic units of energy?

A. Like I guess I don't understand your question.

Q. I don't know how to make it any clearer.

A. Are you asking me like how energy's measured, like with British thermal units, things like that, or are you asking how heat's transferred?

Q. No, I'm asking you what are, how, what are the basic units of energy called? How are they identified?

A. Like kinetic energy, energy, things like that, is that what you're referring to?

Q. No. I don't...

A. I don't know how to answer your question.

Q. Okay. That's fair.

A. All right.

Q. What are the basic units of power?

A. I don't know how to answer your question again, I'm sorry, I don't understand what you're asking.

Q. What is a watt, W-A-T-T?

A. It's an output of electricity, or I think it can be applied to heat and things like that, but commonly referred to in electricity.

Q. How is the size of a fire measured?

A. In a number of ways. The heat output, if you're asking that, like how hot it got, or how many BTUs it produced, or if you're asking like the area that it covered or how much damage it did.

Q. What's radiant heat flux?

A. The ... I know what radiant heat is. I don't know the specific definition of radiant heat flux.

THE REPORTER: Flux or flex?

ATTORNEY: Flux, F-L-U-X.

THE WITNESS: Flux, okay.

Q. What is the generally accepted value of radiant heat flux that will result in flashover?

A. I don't know (continued).

It was only after a few highly publicized “arson” cases were examined closely that it became clear that fully involved fires could create patterns of damage that looked remarkably like patterns created by flammable liquids, even when no flammable liquids were present (Lentini, 1992). A study conducted in Oakland, California, after the devastating fires that began on October 19, 1991, revealed that many previously identified “indicators of arson” could be routinely found in structures that burned in fires known to be accidental (Lentini et al., 1992).

Laboratory experimentation demonstrated that the temperature of a normal well-ventilated wood fire was the same or even higher than the temperature of a well-ventilated fire involving liquid hydrocarbons. The liquid hydrocarbon fire has a higher heat release rate (kW) than the wood fire, but the flame temperature (°F or °C) is no different. The proposition that glass would craze in response to rapid heating was disproved. As most chemists have learned, glass will only craze when it is heated and then rapidly cooled.

(Continued) The following excerpt was then offered into evidence as Exhibit 3: It is the position of the International Association of Arson Investigators (IAAI) that NFPA Document 921 is widely recognized as an authoritative guide for the fire investigation profession. In addition, NFPA 921 is an important reference manual, and it sets forth guidance and methodology regarding the determination of the origin and cause of fires. This Association uses NFPA 921, along with other documents, including NFPA 1033, as a foundation for its training and certification programs. The statement reaffirms the IAAI's long-standing recognition of the importance of NFPA 921 to the knowledge and methodology of fire investigation.

"Authoritative" means the guide is an accepted source of information and is known to be accurate and reliable. By its own terms, the document is not a "standard" and is subject to revision and updating on a periodic basis to allow it to remain current with the expanding scientific and technical knowledge in the fire investigation field.

Q. It's the IAAI position statement regarding NFPA 921 and 1033. Why don't you just take a minute and read it.

ATTORNEY: Objection. Objection to the relevancy or what the point is of what the IAAI's position is in this particular case.

Q. Go ahead.

A. Okay, I've read it.

Q. Do you agree with that?

A. No, I don't.

Q. What part don't you agree with?

A. The authoritative part.

Q. You don't believe 921 is authoritative?

A. No, I don't.

Q. When you investigated this case, did you strictly adhere to NFPA 921?

A. Yes.

Q. All right. And the reason you strictly adhered to NFPA 921 is because it's reliable?

A. It's reliable, yes (continued).

Despite the debunking of many fire investigation myths during the 1990s, some authors failed to get the message, and there are textbooks still in print that unwitting criminal justice professionals may encounter that ensure the myths live on for the next generation of law enforcement officers. For example, the *Encyclopedia of Security Management* (2007) (Fay, 2007), and *Criminal Investigation*, 10th Edition (2013) (Orthmann and Hess, 2013) both repeated the six original fire investigation myths from the NBS *Fire Investigation Handbook*. The dated nature of the (mis) information presented in these two texts has been pointed out to the authors, but the damage done by the publications over the years is unknown.

(Continued)

Q. Would you agree that combustion of hydrogen in the presence of air to form water is the simplest of all chemical combustion reactions?

A. It ... I don't know if ... if that's true or not.

Q. Do you know the chemical symbol for hydrogen?

A. I believe it's just H.

Q. What about hydrogen gas?

A. I believe it's still just H.

Q. What's the chemical symbol for oxygen?

A. O.

Q. What's the chemical formula for oxygen gas?

ATTORNEY: Objection. I do not know how this is possibly relevant, and this is exactly what I was objecting on before.

A. O₂.

Q. What's the concentration of oxygen in air?

ATTORNEY: Objection.

A. What's the concentration of it?

Q. Yeah.

A. Like the air we breathe? 92%. I don't know if that's right or not but it's in that area.

As a result of the shifting of the science, many cases of alleged arson were revisited, and a few convictions were overturned, but the primary beneficiaries of the new knowledge were people who had been accused but not yet convicted, and those who would have been accused by the last generation of investigators. As time went by, the percentage of fires declared to have been intentionally set dropped as fire investigators became aware that their determinations were likely to be seriously challenged (Mann, 2009). The debunking of the fire investigation myths took place largely in a document prepared by the Technical Committee on Fire Investigations within the NFPA, based in Quincy, Massachusetts. NFPA 921, *Guide for Fire and Explosion Investigations*, was first published in 1992, and subsequent editions are published on a 3-year cycle. The document is constantly being updated (NFPA 921, 2014). The eighth edition was published in 2014, and the ninth (2017) edition is being prepared as of the date of this publication.

When NFPA 921 was first published, the vast majority of fire investigators in the US emphatically rejected its guidance because it was so at odds with what they had “learned.” Eventually, however, the fire investigation discipline embraced a more scientific approach to fires, and many of the “old-school” fire investigators retired. The resistance was understandable. To admit to sending an innocent person to prison or causing a family to lose their life's savings is to admit to an unspeakable error. Denial is the easier route.

The first serious challenge to the “old school” of fire investigators came in 1996 in *Michigan Millers Mutual Insurance Company v. Janelle R. Benfield* in which a fire investigator who failed to properly document his observations was excluded from testifying. In the appeal of that exclusion, the IAAI filed an *amicus curiae* brief in which they contended that fire investigators should not be held to a strict reliability

inquiry because fire investigation was “less scientific” than the kind of scientific testing addressed in the *Daubert* decision of 1993 (Burke). Eventually though, there were enough court rulings, including the unanimous Supreme Court decision in *Kumho Tire v. Carmichael*, to persuade the majority of fire investigators that it was necessary to accept the scientific method recommended by NFPA 921.

It is difficult to state exactly when NFPA 921 became “generally accepted by the relevant scientific community,” but 2000 was an important turning point. That year, the US Department of Justice released a research report entitled *Fire And Arson Scene Evidence: A Guide For Public Safety Personnel* (Fig. 3.5), which identified NFPA 921 as a “benchmark for the training and expertise of everyone who purports to be an expert in the origin and cause determination of fires.” That same year, the IAAI for the first time endorsed the adoption of the new edition of NFPA 921.

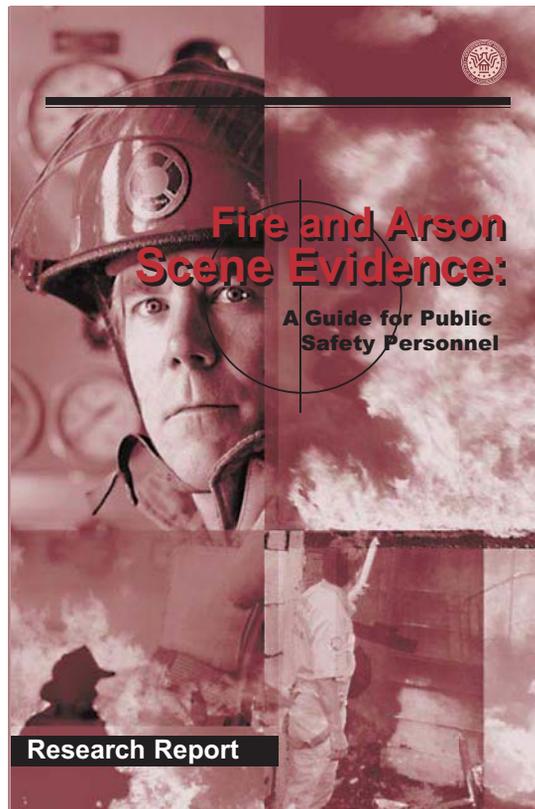


FIGURE 3.5

Cover of the US Department of Justice publication (2000) that embraced the use of NFPA 921.

THE QUESTIONABLE VALIDITY OF FIRE ORIGIN DETERMINATION

The situation today is dramatically improved from 30 years ago, but the fire investigation profession is still struggling to understand the complexities of fire behavior. Recent developments have made abundantly clear that as with many disciplines, “the more one learns, the less one knows.” This point was brought home in 2005 and 2007 when agents of the US Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), which investigates many of the high-profile fires in the US today, conducted studies that reflected rather poorly on the reliability of fire investigators’ determinations of where a fire started. It is axiomatic that unless one finds the correct origin (defined as the *place* where fuel, oxygen, and an ignition source come together), one is likely to come up with an incorrect cause determination. In the 2005 study, two test fires were set in single-room structures and allowed to burn for 2 min after flashover.

Here, an investigator (CFI) was testifying in a civil arson case. His arson determination was based solely on the appearance of a “pour pattern” in a fully involved room (November 10, 2010).

- Q. What is your estimate of the heat release rate of the individual fuel packages in the room?
 A. I don’t know.
- Q. Did you ever come to that ... did you ever have an opinion as to that?
 A. No.
- Q. What is your estimate of the number of kilowatts or megawatts that the fire would have needed to bring the room to a flashover?
 A. I don’t know.
- Q. Did the room have a flashover?
 A. I don’t know.
- Q. [Quoting NFPA 921-08 at 6.3.7.8.] Do you agree that irregular patterns such as those that appeared on the floor of the [subject] residence can be created by fires that do not involve ignitable liquid, and I’m going to refer to that definition of irregular patterns?
 A. No.
- Q. Based on your experience, do you believe you know a flammable liquid pour pattern when you see one?
 A. Yes (continued).

Flashover is a transition point in a structure fire’s development where a “fire in a room” becomes a “room on fire.” This happens when a hot gas layer develops at the ceiling. The fire serves as a “pump” to increase the volume and temperature of that hot gas layer until it begins to radiate its heat in all directions, including downward. When the temperature approaches 1200°F, every exposed combustible surface in the room ignites more or less simultaneously. The diagrams in [Fig. 3.6](#) below illustrate this progression.

Fifty-three investigators were shown the two rooms and asked to write down the quadrant in which they believe the fire originated. Relying on their interpretation of the fire patterns and their belief that the lowest and deepest char indicated the origin, 50 of the 53 selected the wrong quadrant. In the second room, the results

were the same. Only 3 of 53 correctly identified the quadrant of origin. Fig. 3.7 shows the fire pattern that most investigators thought indicated the origin. Fig. 3.8 shows the fire pattern above the true origin.

(Continued)

Q. What's your definition of "fire chemistry"?

A. I'm not really sure how I would define that.

Q. Well, what is your understanding of what fire chemistry means?

A. The ... I don't know.

Q. Do you agree that combustion of hydrogen in the presence of air to form water is the simplest of all chemical combustion reactions?

A. Can you restate that?

Q. Do you agree that the combustion of hydrogen in the presence of air to form water is the simplest of all chemical combustion reactions?

A. I don't know.

Q. What is the chemical symbol for hydrogen?

ATTORNEY: Object to the form of the question.

A. I don't know.

Q. Do you agree that the combustion of methane is the simplest of all combustion reactions involving a hydrocarbon?

A. I don't know.

Q. What is the chemical formula for methane?

ATTORNEY: Object to the form.

A. I don't know.

Q. What's the chemical reaction for the combustion of methane?

ATTORNEY: Object to the form.

Q. If I gave you a piece of paper, would you be able to write it down?

A. No.

Q. What courses have you taken that would qualify you as postsecondary education in thermodynamics?

A. I don't know.

Q. Do you know what the definition of "thermodynamics" is?

A. No (continued).

In the 2007 study, three test fires were set and allowed to burn for 30 s, 70 s, and 3 min beyond flashover. Again, investigators were asked only to choose the quadrant where they believe the fire originated. For the fire with 30 s of full room involvement, 59 of 70 investigators correctly identified the quadrant of origin. For the fire with 70 s of full room involvement, 44 of 64 investigators who chose to identify a quadrant of origin got it correct. Six investigators admitted that they could not tell. That number rose to 17 investigators for the fire that burned for 3 min beyond flashover when only 13 of the 53 who ventured a guess correctly identified the quadrant of origin. That number is no higher than it would be if the quadrant of origin had been selected at random or if the investigators had depended on two coin

(Continued)

Q. Do you know what the relationship between temperature, volume, and pressure is?

A. No.

Q. Okay. What are the basic units of energy?

A. I believe it's endothermic, exothermic, and I don't recall.

Q. Well, would the basic units of energy be described or referred to as Joules, J-O-U-L-E-S?

A. I don't know.

Q. What are the basic units of power?

ATTORNEY: Object to the form.

A. Amps, watts.

Q. If I refresh your recollection and said "watts" or "kilowatts," would that refresh your recollection?

A. Yes.

Q. What is a "watt"?

A. I don't know.

Q. Is it 1 J per second?

A. I don't know.

Q. What is "radiant heat flux," F-L-U-X?

A. Again, I can refer to 921.

Q. Okay.

A. It discusses radiant heat. I don't see radiant heat flux.

Q. If I walked outside on a cloudless day at noon, what is the radiant heat flux that a square meter of earth's surface is receiving from the sun, would you know?

A. No (continued).

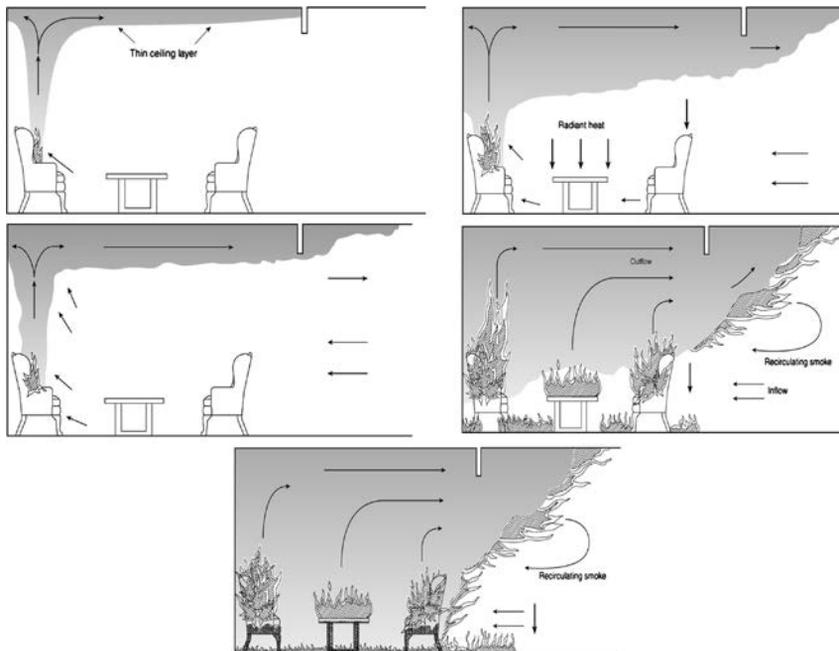


FIGURE 3.6

Sequence of events in the development of a typical compartment fire.

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**FIGURE 3.7**

Large, conspicuous ventilation-produced pattern on the wall opposite the door, incorrectly identified as the origin of the fire by many investigators in the 2005 Las Vegas test. There was no competent ignition source or fuel source at the base of the pattern. The wide base on the pattern may have led some investigators to believe that an ignitable liquid was spread along the wall.

**FIGURE 3.8**

Roughly V-shaped fire pattern located above the true origin of the Las Vegas test fire.

tosses (Carman, 2009). These results caused significant consternation in the fire investigation community. Origin determination is supposed to be a fire investigator's core competency, but these tests suggested that unless the origin is obvious to an untrained person, the fire investigation profession is not up to the challenge of determining even where the fire began.

What misleads fire investigators in the case of full room involvement is ventilation-generated fire patterns, which are created only after flashover and have no relationship to the origin of the fire. Once flashover occurs, the oxygen concentration in the room drops to near zero, so burning at the origin can practically stop. The room is charged with hot combustible fuel, the products of combustion, which themselves can only burn in the presence of sufficient oxygen. Thus, the most intense burning takes place where that fuel finds an oxygen source.

Interpreting ventilation-generated patterns is not a straightforward exercise. The ventilation that comes in through a door may create a fire with a radiant heat flux of 150 kW/m^2 on the wall opposite the door. Fig. 3.9 shows the output of a computer model of the 2005 Las Vegas test fire and explains why there was such a large fire on the wall opposite the door. Every fire pattern in a fully involved room needs to be examined to determine whether it can be explained in terms of ventilation, and if it can, the investigator needs to look elsewhere for the origin.

(Continued) Here, the same investigator is testifying on a later civil arson case, opposed by the same law firm. This time the investigator bases his arson determination on a “pour pattern” and two alleged areas of origins with contiguous burning (October 4, 2013).

Q. Do you recall giving a deposition on November the 10th of 2010 in the [previous case]?

A. Yes, I do.

Q. I'll give you a copy of that deposition so that you'll have it. Do you recall being asked on page 74...

ATTORNEY: A copy for counsel as well.

Q. Do you recall on page 74, you were asked, “Do you agree that the combustion of hydrogen in the presence of air to form water is the simplest of all chemical combustion reactions,” and your answer was “I don't know”?

A. Yes.

Q. Were you under oath when you gave that answer?

A. Yes, I was.

Q. And was that in November of 2010?

A. Yes.

Q. And was this investigation that you did in this [case] August and September of that same year prior to that deposition?

A. I believe so.

Q. Is it fair to say that your investigation you conducted in [this case] was in August and September of 2010 and the deposition I've just quoted was in 2 months thereafter, November?

A. Yes.

Q. Do you know what the chemical symbol for hydrogen is?

A. I believe it's H.

Q. Do you know what the chemical formula for hydrogen gas is?

A. No.

Q. Do you know what the chemical reaction for the combustion of hydrogen is?

A. I'm sorry?

Q. Do you know what the chemical reaction for the combustion of hydrogen is as it relates to fire science?

A. No.

Q. Do you know if the combustion of methane is the simplest of all combustion reactions involving a hydrocarbon?

A. I'm not sure (continued).

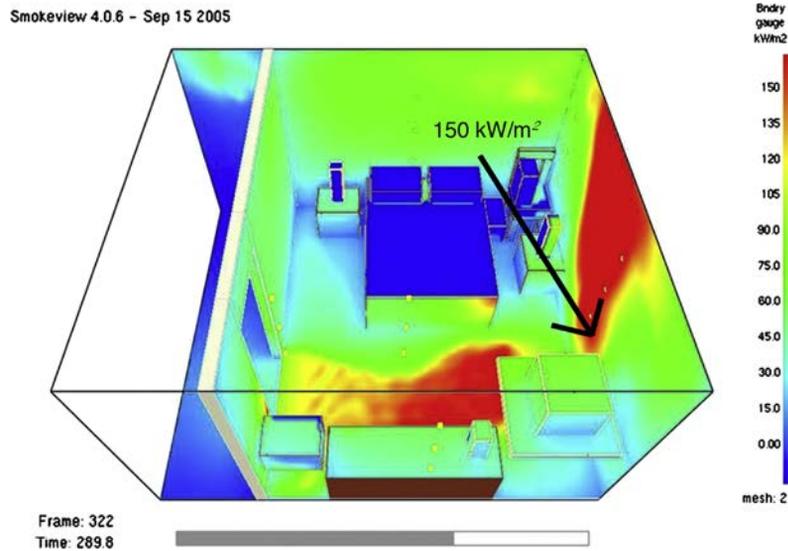


FIGURE 3.9

Output of a fire dynamics simulator computer program used to model the Las Vegas test fire. Because of the influx of oxygen from the doorway, a large, but not terribly meaningful fire pattern developed on the opposite wall.

Adding to the complexity of origin determination is the recently discovered fact that if the origin is elevated above the floor, say on a range top, the development of the hot gas layer might even lead a fire investigator to choose the wrong room of origin. Carman describes an experiment where a fire that started in the kitchen caused the adjacent living room, but not the kitchen, to undergo flashover (Carman, 2011).

Of course, the problem with identifying the wrong point of origin or area of origin is that the ignition source and the first fuel ignited will not be there. Using the discredited methodology called “negative corpus,” investigators will state that there were no potential sources of accidental ignition at the “origin,” and therefore the fire “must have been” intentional. Investigators might then opine that the first fuel ignited “must have been” a flammable liquid, and the ignition source “must have been” an open flame that whoever poured flammable liquid took with them. There may even be a ventilation induced “irregular pattern” on the floor at the base of the fire pattern determined to have been located just above the “origin.” When one considers how fires can be ventilated, keep in mind that usually the hot gases and flames exit the top of the opening, while cool fresh air is drawn in at the bottom. This will result in floor level burning, which, prior to the 1990s, was believed to indicate flammable liquids burning on the floor because as we all know, “heat rises.” An incorrect origin determination followed by negative corpus reasoning led to the fire damage shown in Fig. 3.10 being incorrectly characterized as an arson fire.

(Continued)

Q. Do you know what the chemical formula for methane is?

A. No, I don't.

Q. Do you know what the chemical reaction for the combustion of methane is?

A. No.

ATTORNEY: Object to the form.

Q. Do you know how many volumes of air does it take to react to one volume of methane?

A. No, I don't.

ATTORNEY: Object to the form.

Q. In fire science and in fire investigations, is it useful to know the relationship between temperature, volume, and pressure?

A. Yes.

Q. What is that relationship between temperature, volume, and pressure?

A. Well, it produces heat under pressure, so the amount of pressure on substances would be important.

Q. Do you recall being asked whether you knew the relationship between temperature, volume, and pressure on November the 10th, 2010, in the deposition in the [other] matter?

A. Yes.

Q. Do you recall the question "Do you know what the relationship between temperature, volume, and pressure is," and your answer was "No"...

A. Yes.

Q. ...page 75?

A. Sorry.

Q. Okay. And were you under oath back in November the 10th of 2010?

A. Yes.

Q. All right, sir. In relationship to fire dynamics and fire investigations, what are the basic units of energy?

A. I believe it's exothermic and endothermic (continued).



FIGURE 3.10

The V-shaped pattern in the upper right was incorrectly identified as the origin of the fire. The pattern was created late in the fire as evidenced by its location on the interior of the second layer of drywall. The pattern was the result of ventilation. Because he was unable to locate any ignition source at the base of the V, the investigator concluded that the fire must have been set.

In a compartment fire, heat rises only until it meets an obstruction such as a ceiling, and then the hot gas layer forms. This causes fire behavior that is unfamiliar to individuals who know only about unconfined fires, such as trash fires and campfires. Such people are easily misled. Once the radiant heat flux from the hot gas layer reaches a value of approximately 20 kW/m^2 , every exposed combustible surface in the room ignites within a matter of a few seconds. This includes floors and floor coverings. Fire burning on a floor is only “unnatural” if the floor burns prior to flashover.

COMMON MISINTERPRETATIONS OF FIRE ARTIFACTS

The understanding of the phenomenon of flashover has been critical to the improvement of the accuracy of fire investigation, but the profession still has a long way to go. There are still far too many investigators who believe in the fire myths and far too many who believe that they can, based on their years of experience, identify a flammable liquid “*pour pattern*” by visual observation alone. Such individuals are subject to a reliability challenge based on NFPA 921, which has warned against such practices in ever-stronger terms since its first edition. The 2014 edition carries these warnings about “irregular patterns.”

(Continued)

Q. What are the basic units of power?

A. Joule.

Q. Do you know how a watt relates to a joule?

A. No. I can reference it in 921. I know it's documented, but...

Q. You can find it in there if you looked?

A. Yes.

Q. Okay. What is radiant heat flux?

A. I believe it's the ... I think it's the area that's divided in a compartment, the area of heat.

Q. Okay, sir. If you were to measure ... try to measure radiant heat flux, how would you measure it?

A. I don't know.

Q. Do you know what the generally accepted value of radiant heat flux is that will result in a flash-over fire?

A. No.

Q. You mentioned you took a 6-h course in computer fire modeling. Do you know what mathematical modeling is used for?

A. Not specifically.

Q. Do you know the difference between a zone model and a field model?

A. No, I'm not familiar with that.

6.3.7.8 Irregular Patterns. Irregular, curved, or “pool-shaped” patterns on floors and floor coverings should not be identified as resulting from ignitable liquids on the basis of visual appearance alone. In cases of full room involvement, patterns similar in appearance to ignitable liquid burn patterns can be produced when no ignitable liquid is present.

6.3.7.8.2 Irregular patterns are common in situations of postflashover conditions, long extinguishing times, or building collapse. These patterns may result from the effects of hot gases, flaming and smoldering debris, melted plastics, or ignitable liquids. If the presence of ignitable liquids is suspected, supporting evidence in the form of a laboratory analysis should be sought.

6.3.7.8.5 The term *pour pattern* implies that a liquid has been poured or otherwise distributed and therefore is demonstrative of an intentional act. Because fire patterns resulting from burning ignitable liquids are not visually unique, the use of the term pour pattern and reference to the nature of the pattern should be avoided. The correct term for this fire pattern is an irregularly-shaped fire pattern. The presence of an ignitable liquid should be confirmed by laboratory analysis. The determination of the nature of an irregular pattern should not be made by visual interpretation of the pattern alone.

NFPA 921 contains more warnings about this particular misinterpretation than any others. The reason is that the number of wrongful convictions that have occurred as a result of fire investigators making this misinterpretation is quite large.

One of the first arson convictions overturned as a result of the new knowledge of flashover-generated patterns was that of Ray Girdler in Arizona. Mr. Girdler was convicted based on low-burning, irregular patterns, crazed glass, and a medical examiner's unsupported opinion that the high carboxyhemoglobin (COHb) levels in Girdler's wife and daughter indicated an accelerated fire. After an extraordinary 11-day evidentiary hearing, the trial judge (James Sult, the same judge who had sentenced Girdler to life without parole 8 years earlier) ruled that the artifacts relied upon as evidence of arson were now known to result from accidental as well as intentional fires.

This is the case with most overturned arson convictions. The *corpus delicti*, which the state is supposedly required to prove beyond a reasonable doubt, is later proved to have no scientific basis. The visual (mis)interpretation of irregular patterns is usually a factor. In these cases, it frequently happens that the laboratory analysis has come back with negative results. Laboratory analysis is considerably more objective than fire scene analysis, but laboratory errors have been important factors in several miscarriages.

If fire scene investigators incorrectly characterize an irregular pattern as one caused by an ignitable liquid, then the laboratory incorrectly identifies gasoline in a debris sample, the suspect's goose is cooked unless the lab error is detected by the defense. There is (usually) no good reason for there to be gasoline on the living room carpet, and if the lab finds it, the scene investigator's confidence in his findings will be boosted to the point where it is unshakeable. For this reason, it is imperative that the lab results be examined early in the litigation process. If the gasoline determination is a righteous one, there is little point in contesting the incendiary classification of the fire. Note that the finding of almost any other ignitable liquid residue besides gasoline may have an innocent explanation.

Shoes, for example, are known to contain a variety of hydrocarbon solvents. Floor coatings may contain solvents, such as mineral spirits, that may be detectable for decades (Lentini, 2001). Newsprint may test positive for kerosene, and carbonless

forms often test positive for a mixture of compounds commonly found in lamp oil (Lentini et al., 2000). In the absence of a comparison sample, the contribution of the background may never be known, and meaningless findings of a trace amount of an ignitable liquid residue will be presented as “evidence of an accelerant.”

It was a false finding of gasoline that led to the wrongful conviction of David Lee Gavitt in Michigan. Fire investigators in 1985 declared the fire that killed his wife and two children was intentionally set in three places using a flammable liquid. A profoundly unqualified chemist used profoundly poor methodology to wrongly conclude that 2 of 17 debris samples were positive for gasoline. The error was not discovered until 2011 when the author was asked to examine the laboratory data. There were numerous other errors in the case, but it took 2 more years and a review by the ATF requested by the prosecutor before Mr. Gavitt was finally released (Plummer and Syed, 2012).

Another wrongful conviction overturned was that of Weldon Wayne Carr in Georgia. He was convicted in 1994, despite the fact that 12 samples collected by the fire investigator tested negative at two different laboratories. Prosecutor Nancy Grace, in her last trial before hiring on at CNN, used the positive alerts of a canine named Blaze to persuade the jury that ignitable liquids were involved in the fire. The Georgia Supreme Court found that using unconfirmed canine alerts was akin to the earliest lie detector tests.

The first recorded lie detector test was in ancient India where a suspect was required to enter a darkened room and touch the tail of a donkey. If the donkey brayed when his tail was touched the suspect was declared guilty, otherwise he was released. Modern science has substituted a metal electronic box for the donkey but the results remain just as haphazard and inconclusive.

Carr vs. State (1997)

The use of unconfirmed canine alerts is an insult to the collective intelligence of courts and juries, but overzealous prosecutors will present this pseudoscience anyways. Analogies to drug dogs and explosive dogs are inapt. If a drug dog or an explosive dog alerts to a suitcase, and no drugs or explosives are found, nobody is even arrested. But in the case of accelerant-detecting canines, the handlers (who are not scientists) believe their dogs are more sensitive than the laboratory and insist that the alerts, which are presumptive tests at best, mean that the fire was intentionally set. The sensitivity argument is bogus. A competent laboratory analyst can detect quantities of ignitable liquid as small as 1/500th of a drop (0.1 μL) (Lentini, 2012a,b).

In 1996, the NFPA Technical Committee on Fire Investigations declared, “a fraud is being perpetrated on the judicial system” (NFPA Technical Committee on Fire Investigations, 1996) and stated in NFPA 921 that unconfirmed canine alerts should not be considered validated (NFPA 921-14: 17.5.4.7.1). The misuse of unconfirmed alerts diminished but did not stop entirely. The Canine Accelerant Detection Association, the largest professional association of canine handlers, denounced the continued attempt to introduce unconfirmed alerts in 2012. They stated, “... no Prosecutor, Attorney or ADC Handler should ever testify or encourage testimony

that an ignitable liquid is present without confirmation through laboratory analysis” (Officers And Directors of the Canine Accelerant Detection Association, 2012).

Another common cause of wrongful classification of accidental fires as intentional is the fire investigator’s perception of “multiple origins.” When flashover occurs, all of the available exposed fuel ignites nearly simultaneously. The ignition results in the burning of floors and baseboards, even baseboards and floors remote from the place where the fire started. As a result, a fire that starts in one area of a building could, through flashover, ignite fuel in another area of the building, and those two areas could burn more intensely than the area in between due to differences in the available ventilation. Thus, multiple origins are perceived where none actually exist.

In January 2013, the Defense Research Institute sponsored a seminar entitled *Fire Science and Litigation: Smoke and Mirrors, Using Science to Light the Way* in which the science of origin determination was discussed, including a discussion by Steven Carman, the author of the 2005 Origin Accuracy paper and a highly respected former ATF agent, entitled “The Impact of Ventilation in Fire Investigation.” The following is Mr. Carman’s advice on the possibility of confusion caused by ventilation.

Areas of pre- and post-flashover damage created during the same fire can be far removed from each other and show no apparent connection. The post-flashover damage can be far more severe and appear indicative of longer burning. Investigators unfamiliar with post-flashover burning behavior might conclude that separate fires were set independently of the others. Such analyses can mistakenly lead to incorrect origin determinations and cause classifications.

There is no question that accidental fires almost always begin in one and only one place. Thus, if there is **reliable** evidence of multiple origins, this is powerful evidence indicating that a fire was set. Unfortunately, many fire investigators believe they can discern multiple origins even after full room involvement and even when all of the damage is contiguous.

NFPA 921 discusses multiple origins and warns about potentially confounding influences that will cause a fire investigator to be misled. The following guidance is provided.

24.2.1 Multiple Fires. Multiple fires are two or more separate, nonrelated, simultaneously burning fires. The investigator should search to uncover any additional fire sets or points of origin that may exist. In order to conclude that there are multiple fires, the investigator should determine that any “separate” fire was not the natural outgrowth of the initial fire.

24.2.1.1 Fires in different rooms, fires on different stories with no connecting fire, or separate fires inside and outside a building are examples of multiple fires. A search of the fire building and its surrounding areas should be conducted to determine whether there are multiple fires.

24.2.1.2 Separate fires that are not caused by multiple deliberate ignitions can result from the following:

1. fire spread by conduction, convection, or radiation
2. fire spread by flying brands

3. fire spread by direct flame impingement
4. fire spread by falling flaming materials (i.e., drop-down), such as curtains
5. fire spread through shafts, such as pipe chases or air conditioning ducts
6. fire spread within wall or floor cavities within “balloon construction”
7. overloaded electrical wiring
8. utility system failures
9. lightning
10. rupture and launching of aerosol containers

Han Tak Lee was convicted of setting the 1989 fire that killed his daughter at a church retreat in rural Pennsylvania. The “science” used to “prove” that the fire was intentionally set included an assertion that the fire had nine separate points of origin in one fully involved room. The state alleged the use of more than 60 gallons of a diesel fuel/gasoline mixture, despite the fact that no container large enough to accommodate this astonishing volume existed in the small cabin where the fire occurred. Mr. Lee’s defense counsel argued that it was the mentally disturbed victim who set the fire, but the District Attorney countered that she was not clever enough to have mixed the fuels together. He argued, erroneously, that three samples that tested positive each contained “the very same thing,” despite the fact that the chemist had said no such thing when testifying.

Those offering testimony against Mr. Lee were no more qualified than the investigators described at the beginning of this chapter, who do not know the basic units of energy. One of the investigators stated that fire burned abnormally fast because it exceeded the “standard time–temperature curve.” That curve describes how to run a fire resistance test, but has no relationship to how an actual fire behaves. That witness also claimed to have investigated 15,000 fires in a 20-year career (do the math.) Some 10 years after the trial, the state’s lead investigator, writing in a letter to the editor, defended his investigation, stating that his methodology had not been discredited until after the trial.

It required 21 years of litigation before the state conceded that all of the so-called indicators of arson were invalid. The state was left with the three samples, having “lost” the original data. When those samples were reanalyzed and compared in 2012, they were clearly not “the very same thing” and were easily distinguishable.

In 2014, Federal Magistrate Judge Martin Carlson wrote a remarkable 45-page report and recommendation stating that Mr. Lee should be freed after serving 25 years of a life sentence. The report began with these words: “Slow and painful has been man’s progress from magic to law.” He continued, “Sometimes, with the benefit of insight gained over time, we learn that what was once regarded as truth is myth, and what was once accepted as science is superstition. So it is in this case” (Tak Lee, 2014).

CONCLUSION

The Lee case presents a microcosm of all that has changed about fire investigation over the last 40 years. NFPA 921, for its first three editions, described fire investigation as “a complex endeavor involving both art and science.” The language was changed in 2001

(and thereafter) to read “a complex endeavor involving skill, technology, knowledge, and science.” As science has become dominant, the situation has improved, but there is still a significant cadre of investigators who believe in the myths and who are unable to apply science properly in their investigations because they are not scientists and have no plans to become scientists. Thus, there is still a need for vigilance on the part of those who consume the work product of this profession.

In their analysis of the disastrous Cameron Todd Willingham case, the Texas Forensic Science Commission made a list of 17 recommendations for improving the practice of fire investigation and its use in the justice system. Perhaps the most important of the recommendations called for an increase in judicial scrutiny. The Commission recommended that admissibility hearings (also referred to as Daubert/Kelly hearings) be conducted in all arson cases due to the inherently complex nature of fire science and the continuously evolving nature of fire investigation standards ([Report of The Texas, 2011](#)). Such hearings will facilitate the “bifurcation” necessary to prevent conviction of individuals based on character assassination rather than on good science.

In the final analysis, however, the situation is unlikely to improve until the people and organizations that hire fire investigators are able to offer salaries sufficiently high to attract educated scientists.

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