



# NFPA 921'S IMPACT ON FIRE SCENE RECONSTRUCTION

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## INTRODUCTION

Courts now prefer science-based methods when describing and providing testimony in fire scene reconstruction. These science-based methods include a reliance on The National Fire Protection Association's *NFPA 921 – Guide for Fire and Explosion Investigations*, as well as on other expert treatises.

Fire scene reconstruction is the process of determining the most likely development of a fire using a scientifically based rationale. Reconstruction follows the fire from ignition to extinguish-

ment, and it explains aspects of the fire and smoke development, the role of fuels, effects of ventilation, the impact of manual and automatic extinguishment, the performance of the building, life safety features, and manner of injuries or death.

Forensic fire scene reconstruction relies upon a comprehensive review of the fire pattern damage, sound fire protection engineering principles, human factors, physical evidence, and an appropriate application of the scientific method. These factors often form the basis for an expert opinion as to the most probable origin and cause of the fire or explosion. The expert opinion may be part of a written report or the basis for oral testimony in depositions or courtrooms.

In order to be effective, these expert opinions must be able to pass the eventual scrutiny of cross-examination during sworn depositions, peer review, and courtroom testimony. Recent court decisions place more weight on expert forensic testimony based upon scientific, rather than merely experience-based, knowledge.<sup>1</sup>

When determining the origin and cause of a fire, a comprehensive reconstruction often involves a fire engineering analysis that tests various scenarios. This analysis may use fire modeling to compare actual events with predicted outcomes by varying causes and growth scenarios. This engineering analysis adds value, understanding, and clarity to an already complex fire scene investigation.

## THE NEED FOR SCIENCE IN FIRE SCENE RECONSTRUCTION

A federal conference in November 1997 assessed the current state of the art and identified technical gaps in fire investigation.<sup>2</sup> *The International Conference on Fire Research for Fire Investigation* concluded that many scientific gaps existed in the methodology and principles used to reconstruct fire scenes.

### The Scientific Method

The underpinning of forensic fire scene reconstruction is the use and application of relevant scientific principles and research in conjunction with a systematic examination of the scene. This is particularly true in cases that later require expert witness opinions. The scientific method, which embraces sound fire protection engineering principles combined with peer-reviewed research

and testing, is the best approach for conducting fire scene analysis and reconstruction. *NFPA 921 – Guide for Fire and Explosion Investigations* defines the scientific method as the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of a hypothesis.<sup>3</sup>

### Benefits of the Scientific Method

There are numerous benefits for using the scientific method to examine fire and explosion cases, including:

- Acceptance of the methodology in the scientific community,
- Use of a uniform, peer-reviewed protocol of practice, such as *NFPA 921*, and
- Improved reliability of testimony from opinions formed using the scientific method.

The use of the scientific method is well received in both the technical and research communities. An investigation conducted using this approach is more likely to be embraced by those who would tend to doubt a less vigorously conducted probe. Second, the scientific method is an accepted protocol of practice for *NFPA 921*.

Those persons ignoring or deviating from *NFPA 921* practices would bring closer scrutiny to their reports and opinions. Another guide that repeatedly cites *NFPA 921* is the National Institute of Justice's *Fire and Arson Scene Evidence: A Guide for Public Safety Personnel*.<sup>4</sup> The NIJ guide notes that actions taken at the scene of a fire or arson investigation can play a pivotal role in the resolution of a case.

A thorough investigation is key to ensuring that potential physical evidence is neither tainted nor destroyed, nor potential witnesses overlooked. More importantly, expert testimony in fire and

explosion cases will rely more heavily on opinions formed using the scientific method. Recent U.S. Supreme Court decisions underscore these principles, with many state courts following the trend.

### **Engineering Analysis as a Scientific Method**

Fire engineering analysis, which can range from a basic “back-of-the-envelope” first-level calculation to a sophisticated fire model, is an important step in fire scene reconstruction that provides numerous benefits. Historical investigations using fire engineering analysis have accurately assessed fire development, measured the performance of fire protection features and systems, and predicted the survivability and behavior of people during the incident.

Several significant fire engineering analysis studies have been undertaken by the NIST over the years. These detailed reports consist of the Dupont Plaza fire,<sup>5</sup> First Interstate Bank Building fire,<sup>6</sup> Pulaski Building fire,<sup>7</sup> Hillhaven Nursing Home fire,<sup>8</sup> Happyland Social Club Fire,<sup>9</sup> 62 Watts Street fire,<sup>10</sup> and Cherry Road fire.<sup>11</sup> Some form of fire engineering analysis is now considered a necessary step in comprehensive fire scene analysis and reconstruction.

### **Benefits of Engineering Analysis**

Fire engineering analysis, combined with modeling, offers the following benefits:

- Establishes the basis for the collection of data needed to construct event time lines;
- Provides ignition sequences, and failure modes and effects analysis (FMEA);
- Invites application of the scientific method when testing hypotheses and validating fire scene reconstruction;
- Provides a viable alternative to full-scale fire testing and extends full-scale test results to differing ranges of conditions (sensitivity analysis);
- Provides answers to many important questions raised on human factors, ignition sequences, equipment failure, and fire protection systems (detectors, alarms, and sprinklers); and

- Identifies important future research areas in fire investigation.

Historically, the use of engineering analysis and modeling in fire scene reconstruction was conducted on a case-by-case basis, due mainly to the complexity of the process. A vast amount of

knowledge and time was required to collect and analyze the information on the development of the fire.

Engineering analysis and modeling are becoming more commonplace. Despite the complexity of the processes, fire engineering analysis and modeling should be applied to cases involving

multiple deaths, or cases where code deficiencies contributed to the fire, or in the anticipation of extensive civil or criminal litigation.

A fire engineering analysis often uses fire modeling to compare actual events with predicted outcomes using varying fire causes and growth scenarios. Surface temperatures on the walls can be calculated by the fire model and displayed using a color-coded gradient scale. Results from the surface temperatures can be compared with burn patterns to confirm the sequence of the fire. This analysis often adds value, understanding, and clarity to complex fire scene investigation. Fire modeling can also serve as an alternative to full-scale fire testing to explain burn patterns and the fire dynamics involved.

Fire engineering analysis and modeling may also provide answers to important questions raised during fire investigations. These questions might include the following:

- What was the most probable cause of the fire (i.e., can several possible causes be eliminated)?
- How long did it take to activate fire or smoke detectors and sprinklers?
- What were the smoke and carbon monoxide levels in each room after 10 min?
- Why didn't the occupants of the building survive the fire?
- Was an accelerant used in the fire, and if so, what type?
- How much time elapsed from when the owner of the structure left the building until the fire reached flashover?
- Did a negligent building design or failed fire detection and suppression system contribute to the growth of the fire?
- What changes to policy, building, or fire codes are necessary to ensure that similar fires will not occur in the future?

Discussion and cooperative research between fire investigators and fire protection engineers underscore the need to include fire modeling as an integral and required step in fire scene reconstruction. Fire investigators and engineering professionals need to collaborate further in order to expand their

knowledge and validate the methods shared in common by both groups.

### THE SCIENTIFIC METHOD AND NFPA 921

Listed below is an annotated seven-step systematic process, based upon *NFPA 921*, for applying the scientific method to fire investigation and reconstruction.

- 1. Recognize the Need.** First responders must recognize that a scene needs to be protected until a full investigation can be started. This includes not only the origin and cause of the event, but also recognizes the responsibility to determine if future fires, explosions, or loss of life can be prevented through new designs, codes, or enforcement strategies.
- 2. Define the Problem.** A tentative investigative plan should be devised to preserve and protect the scene, determine the cause and nature of the loss, conduct a needs assessment, formulate and implement a strategic plan, and prepare a report.
- 3. Collect Data.** Facts and information about the incident should be collected through direct observations, measurements, photography, evidence collection, testing, experimentation, historical case histories, and witness interviews. All collected data should be subject to verification of how it was legally obtained, its chain of custody, and notation as to its reliability and authoritative nature.
- 4. Analyze the Data.** The investigator relies upon his or her knowledge, training, and experience in evaluating the totality of the data. This subjective approach to the analysis may include knowledge of similar loss histories (observed or obtained from references), training and understanding of fire dynamics, fire testing experience, and experimental data.
- 5. Develop a Working Hypothesis.** Based upon the data analysis, a tentative working hypothesis should be developed to explain the fire's origin, cause, and development that is con-

sistent with on-scene observations, physical evidence, and testimony from witnesses.

- 6. Test the Working Hypothesis (Deductive Reasoning).** The working hypothesis should be compared with all other known facts, the incidence of prior loss histories, authoritative fire test data, sound published treatises, and experiments. The working hypothesis should be used to eliminate all other reasonable origins and causes for the fire or explosion. The investigator should recommend the collection and analysis of additional data, seek new information from witnesses, and develop or modify the working hypothesis. This may involve reviewing the analysis with other investigators with relevant experience and training. Interactively repeat Steps 4, 5, and 6 until there are no discrepancies between the working hypotheses. By testing various working hypotheses rigorously against the data, those that cannot be conclusively eliminated should still be considered viable.

- 7. Select Final Hypothesis (Conclusion or Opinion).** When the working hypothesis is thoroughly consistent with evidence and research, it becomes a final hypothesis and can be authoritatively presented as a conclusion or opinion of the investigation. If a final hypothesis cannot be determined, the cause should be reported as "undetermined."

### SCIENCE-BASED EVIDENCE

Recently, the U.S. Supreme Court has ruled on the admissibility of expert scientific and technical opinions, particularly as they relate to fire scene investigations. These decisions impact how expert testimony is accepted and interpreted.

Although much controversy exists over these Court decisions, fire and explosion investigation is emerging more as a "science" and less of an "art." This is particularly true when combining the use of the scientific method with relevant engineering principles and research in providing expert witness testimony.<sup>12, 13</sup>

A judge has the discretion to exclude testimony that is speculative or based upon unreliable information. In the case *Daubert v. Merrell Dow Pharmaceuticals*, 509 U.S. 579 1993,<sup>14</sup> the Court placed the responsibility upon a trial judge to ensure that expert testimony was not only relevant but also reliable. The judge's role is to serve as a "gatekeeper" to determine the reliability of a particular scientific theory or technology. The Court defined four criteria to be used by the "gatekeeper" to determine whether the expert's theory or underlying technology should be admitted.

The four-guideline *Daubert* criteria consist of testing, peer review and publication, error rates and professional standards, and general acceptability. In short, expert testimony must rely on a balance of valid peer-reviewed literature, testing, and acceptable practices if it is to be considered credible by the courts.

In a more recent decision,<sup>15</sup> *Kumho Tire Co. Ltd. v. Carmichael*, the Court applied the four-guideline criteria to expert testimony to determine whether it was based upon science or experience.

### Peer Review and Publications

A credible, reliable theory must take into account the body of research that has been compiled, verified, and published by experts in the field. The necessity for credibility underscores advantages of using the scientific method. Recently, there has been a tendency for courts to hold experts to the same standards that scientists use in evaluating each other's work, sometimes referred to as peer review.<sup>16</sup>

Investigators can also participate in peer review when their cases are submitted to supervisors for review. In law enforcement, this is the primary function of supervisory review – to assure that all questions, logical investigative leads, laboratory examinations, and plausible theories are addressed. Some experts develop opinions based solely on the results of tests conducted specifically to support expert testimony.

The *Daubert II*<sup>17</sup> Court places greater weight on testimony based upon pre-existing research that uses the scientific method, as it is considered more reliable.<sup>18</sup> The Eleventh Circuit Court of

Appeals applied *Daubert* and excluded the testimony of a fire investigator in the *Benfield* case.<sup>19</sup> The Court held that the investigation of fires is science-based and that the *Daubert* criteria apply.

*NFPA 921* specifically cautions that "the elimination of all accidental causes to reach a conclusion that a fire was incendiary is a finding that can rarely be justified scientifically." If pursued vigorously, however, the scientific method can be used to demonstrate successfully that the only mechanism for ignition had to be deliberate by demonstrating that all relevant accidental mechanisms had been specifically evaluated, tested, and eliminated.

### Error Rates, Professional Standards, and Acceptability

Under *Daubert*, the Court considers the known or potential rate of error and the existence of acceptable professional standards on the techniques used by the expert. Error rates from repeated tests form the basis for many equations, relationships, and models used to describe fire and explosion dynamics. These error rates are produced during data analysis from fire testing.

A particular practice that has a broad impact on investigators is the *Standard Practice for Examining and Testing Items That Are or May Become Involved in Litigation*.<sup>20</sup> This practice covers evidence (actual items or systems) that may have future potential for testing or disassembly and are involved in litigation.

This practice sets forth the following guidance:

- Documentation of evidence prior to removal and/or disassembly, testing, or alteration,
- Notification of all parties involved, and
- Proper preservation of evidence after testing.

This practice also stresses the importance of safety concerns associated with testing and disassembly of evidence. This is particularly important when dealing with energized equipment or evidence containing potentially hazardous chemicals.

## THE IMPACT ON TESTIMONY IN COURT CASES

The importance of *NFPA 921* has also been cited along with *Daubert* as an interlinking element of expert testimony since it establishes guidelines for the reliable and systematic investigation or analysis of fire and explosion incidents.<sup>21</sup>

Several clusters of recent federal court opinions and rules fall into the following areas.

- Use of investigative protocols, guidelines, and peer-reviewed citations,
- Methodological explanations for burn patterns, and
- Qualifications to testify.

Professional education is paramount in any profession. It is incumbent on all professional fire investigators continuously to read and keep abreast of all relevant fire, engineering, and legal publications and critically evaluate their conclusions with this ever-changing knowledge. Today's knowledge may change with new developments, truly affecting an established hypothesis.

### Use of Guidelines and Peer-Reviewed Citations

In a case involving a residence fire, a number of independent investigators attempted to determine the exact origin and cause of the fire. One investigator, an electrical engineer, offered the opinion that a television set located in the basement family room caused the fire. The plaintiffs sued the television's manufacturer, claiming product liability, negligence, and breach of warranties.<sup>22</sup>

A federal judge hearing this case held a *Daubert* hearing and concluded that the one investigator's causation testimony was inadmissible. The judge cited that the issue in this case was the second Rule 702 factor, that an expert's opinion should be based upon a reliable methodology. The judge noted that the investigator did not use a fixed set of guidelines in determining the cause of the fire. Notably, the investigator did confirm that, even though he was aware of the existence of established guidelines in *NFPA 921* and *Kirk's Fire Investigation*,<sup>23</sup> he relied upon his own experience and knowledge.

During the hearing, the plaintiffs did not submit any books, articles, or witnesses on proper fire causation techniques other than the one investigator. The judge specifically commented on the fact that the one investigator made reference to his reliance on a burn pattern inside the television set. No citations were made to peer-reviewed sources to support this opinion.

### Methodology Needed

A 1996 residential fire started in the corner of a kitchen containing a dishwasher, toaster oven, and microwave oven. The municipal fire marshal concluded that the fire had been caused by the microwave oven, while in a federal civil case, the plaintiff's expert asserted that a defective toaster oven caused the fire.<sup>24</sup>

A senior federal judge held a *Daubert* hearing in which evidentiary and testimonial records were reviewed and ruled that the opinion of the plaintiff's investigator was not admissible under Rule 702. The judge concluded that the plaintiff's investigator did not provide sufficient reliable evidence to support the methodology for investigating the cause of the fire. The judge also noted that the comprehensive nature of *NFPA 921* contained a methodology that could have supported the opinion and tested the hypothesis for the fire's cause.

In a federal civil case, an insurance company sued to recover subrogation paid by the company for fire damage to the property of its subrogors. The judge denied the defendant's motion to exclude the trial testimony of the plaintiff's origin-and-cause expert witness. The judge noted that the expert's testimony is the product of reliable principles based upon the scientific method as outlined in *NFPA 921* and that the expert applied these principles and methods in a reliable and relevant manner to satisfy the admissibility requirements of *Daubert* and the Federal Rules of Evidence 702.<sup>25</sup>

### Methodological Explanations for Burn Patterns

In the case of a building fire, a federal U.S. magistrate denied the plaintiff's mo-

tion to bar opinion testimony as to the origin and cause of the fire at the time of trial.<sup>26</sup> In this case, both a municipal fire department investigator and a private insurance investigator concluded from their examinations of the scene that the fire was incendiary in origin. No physical evidence was taken for laboratory examination.

The plaintiff argued that these investigators were not reliable and their testimonies were inadmissible under Rule 702, because they did not use the scientific method as outlined in *NFPA 921* and relied upon only physical evidence observed at the scene. The case also contained parallels with the *Benfield* case.<sup>19</sup> In denying the plaintiff's motion, the federal magistrate noted in his decision that the investigators were able to provide an adequate methodological explanation for the analysis of burn patterns that led to how they reached their conclusion as to the fire's incendiary origin.

### Methodology and Qualifications

In the case of a residential fire, which resulted in a federal lawsuit for products liability, the judge granted the defendant's motion to exclude the testimony of the electrical engineer citing *Daubert*, Rule 702 and Rule 704.<sup>27</sup> In this case, an insurance company investigator called upon an electrical engineer to remove and examine the charred remains of a bathroom exhaust fan, clock, lamp, timer, compact disc player, computer with printer and monitor, ceiling fan, power receptacle, and power strip. The engineer came to an opinion that a defect in the compact disc player caused the fire. His observations were based on burn patterns in the room, on appliance remains, and on his experience, education, and training.

In his ruling, the judge noted that the training and experience of the engineer did not qualify him to offer an analysis of burn patterns and theory of fire origin. Furthermore, the judge noted that the engineer did not use the scientific methodology recommended by *NFPA 921* to form a hypothesis from the analysis of the data, nor did he satisfy the requirements for expert testimony under *Daubert*. ▲

*This article is based in part upon material from the authors' textbook, Forensic Fire Scene Reconstruction, published by Prentice Hall. ISBN: 0-13-094205-7, ©2004.*

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