OSAC Technical Guidance Document 0005

Strengthening Fire and Explosion Investigation in the United States: A Strategic Vision for Moving Forward

https://doi.org/10.29325/OSAC.TG.0005

Fire & Explosion Investigation Subcommittee

OSAC
Organization of Scientific Area Committees for Forensic Science

OSAC Technical Guidance Document 0005

Strengthening Fire and Explosion Investigation in the United States: A Strategic Vision for Moving Forward

Prepared for
The Organization of Scientific Area Committees (OSAC) for Forensic Science

Prepared by
Fire & Explosion Investigation Subcommittee
Organization of Scientific Area Committees (OSAC) for Forensic Science

April 2021

Document Disclaimer:

This OSAC Technical Guidance Document was produced using a consensus process within the Organization of Scientific Area Committees (OSAC) for Forensic Science and is made available by the U.S. Government. All OSAC members had an opportunity to comment on the document and provide suggestions for revisions on this OSAC Technical Guidance Document. The views expressed in the document do not necessarily reflect the views or policies of the U.S. Government. The document is provided “as is” as a public service, and the U.S. Government is not responsible for its contents.

Any mention of commercial equipment, instruments, or materials in this Technical Guidance Document does not imply recommendation or endorsement by the U.S. Government; neither does it necessarily imply that the materials or equipment identified are the best available.

Abstract

Strengthening Fire and Explosion Investigation in the United States: A Strategic Vision for Moving Forward is a strategic plan for improvements in fire and explosion investigation as a forensic science discipline. The OSAC subcommittee for Fire and Explosion Investigation performed an in-depth examination of the past and current state of fire and explosion investigation and its relationship to the judicial system. The subcommittee then developed a comprehensive series of recommendations for how to improve the practice of fire investigation.

The first edition of NFPA 921 was published in 1992. Much progress has been made since this early recognition of the need to enhance the practice of fire and explosion investigation. The field of fire and explosion investigation can now be said to be in its adolescence, but much work is required to bring it to maturity.

In terms of the impact of NFPA 921 on fire-related litigation, progress has been far more rapid in civil litigation than in criminal matters. Judges and lawyers need to be educated and trained on fire science and investigation to assure that only reliable fire investigations and analyses are presented to juries.

NFPA 1033 has taken its place in defining the qualifications of fire and explosion investigators. The continuing development of NFPA 1033 is needed to support continuing improvements in fire investigation. It has become clear that the current NFPA 1033 educational requirement of a high school degree can no longer be accepted. The 16 knowledge areas which bear on fire and explosion investigation are too sophisticated for investigators to master the needed science and technology working simply from a high school education. Fire is a collection of complex physical and chemical processes that necessitates investigation by those educated in the science and practice of fire and explosion investigation. The day when a BS in one of the physical sciences, engineering, or fire and explosion investigation is the entry-level educational requirement needs to be realized in the coming years.

The field of fire and explosion investigation needs to move toward accreditation of all fire and explosion investigation units. In 2016, the OSAC Fire and Explosion Investigation Subcommittee proposed that NFPA develop a Standard on the Organization and Operation of Fire Investigation Units. That proposal was accepted, a technical committee was formed, and a proposed draft of the standard was submitted to NFPA (NFPA 1321). This standard should provide a foundation for accreditation of fire and explosion investigation units.

Fire and explosion investigation units need to implement information management practices to minimize bias and reduce exposure to task-irrelevant data. Also, there is a need for fire investigation units to fully implement the scientific method and technical review processes to minimize potential bias. All stakeholders need to take responsibility for requiring complete and comprehensive fire and explosion investigation reports.

Sustained funding for fire and explosion investigation research is needed to move the discipline forward. The research agenda detailed in Chapter 7 needs to be implemented. Efforts are required to assure that research for fire investigation is easily accessed by investigators.

Keywords

fire, explosion, investigation, OSAC, strategic plan, vision, NFPA 921, NFPA 1033, education, training, research, certification, accreditation, investigation reports, minimizing bias

Authors

Craig Beyler
Philip Crombie
Chris Connealy
Mark Goodson
John Lentini
Melvin “Dixon” Robin
David Sheppard
Charles “Randy” Watson
Chad Wissinger

Table of Contents

Acronyms / Abbreviations

A2LA - American Association for Laboratory Accreditation
AAFS – American Academy of Forensic Sciences
ACFE - Association of Certified Fraud Examiners
AFCI - Arc-Fault circuit Interrupters
ANAB - ANSI National Accreditation Board
ASTM International - formerly the American Society for Testing and Materials
ATF - Bureau of Alcohol, Tobacco, Firearms, and Explosives
BLEVE - Boiling Liquid Expanding Vapor Explosions
BS – Bachelor of Science
CALEA - Commission on Accreditation for Law Enforcement Agencies
CFE - Certified Fraud Examiner
CFEI - Certified Fire & Explosion Investigator
CFII - Certified Fire Investigation Instructor
CFITrainer -Certified Fire Investigator Trainer
CFPS - Certified Fire Protection Specialists
CFR – Code of Federal Regulations
CI - Certified Instructor
CIFI - Certified Insurance Fraud Investigator
COA - Committee on Accreditation
CPSC – Consumer Product Safety Commission
CVFI - Certified Vehicle Fire Investigator
DOJ – Department of Justice
DOT – Department of Transportation
ECT - Evidence Collection Technician
F - Fahrenheit
FIT - Fire Investigation Technician
FIU - Fire Investigation Unit
FRI - Full-Room Involvement
FRL - Fire Research Laboratory
FSAB - Forensic Specialties Accreditation Board
GC-MS - Gas Chromatography coupled with Mass Spectrometry
GFCI - Ground-Fault Circuit Interrupters
HVAC – Heating Ventilating and Air Conditioning
IAAI - International Association of Arson Investigators
IASIU - International Association of Special Investigation Units
ICAC - Insurance Committee for Arson Control
ICS - Incident Command System
IFMA - International Fire Marshals Association
IFSAC - International Fire Service Accreditation Congress

IGL Canines – Ignitable Liquid Detection Canine
ILR - Ignitable Liquid Residues
ISFI - International Symposium on Fire Investigation Science and Technology
ISO/IEC - International Organization for Standardization and the International Electrotechnical Commission
JPR - Job Performance Requirements
KSA - Knowledge, Skills, and Abilities
LEAA - Law Enforcement Assistance Administration
MS – Master of Science
NAFI - National Association of Fire Investigators
NAS – National Academy of Science
NASFM - National Association of State Fire Marshals
NASP - National Association of Subrogation Professionals
NBS - National Bureau of Standards (now named NIST)
NCFS - National Commission on Forensic Science
NFPA – National Fire Protection Association
NIJ - National Institute of Justice
NIST - National Institute of Standards and Technology
OSAC - Organization of Scientific Area Committees
OSHA – Occupational Safety and Health Administration
PI - Private-sector Fire Investigators
Pro Board - National Board on Fire Service Professional Qualifications
QA – Quality Assurance
SAW - Science Advisory Workgroup
SDS – Safety Data Sheet (formerly MSDS)
SFMO - State Fire Marshal's Office
SFPE - Society of Fire Protection Engineers
SOP - Standard Operating Procedure
TDI - Texas Department of Insurance
TIA - Tentative Interim Amendment
TX FSC - Texas Forensic Science Commission
UL – Underwriters Laboratory
ULTR - Uniform Language for Testimony and Reports

EXECUTIVE SUMMARY

Strengthening Fire and Explosion Investigation in the United States: A *Strategic Vision for Moving Forward* is a strategic plan for improvements in fire and explosion investigation as a forensic science discipline. The OSAC subcommittee for Fire and Explosion Investigation performed an in-depth examination of the past and current state of fire and explosion investigation and its relationship to the judicial system. The subcommittee then developed a comprehensive series of recommendations for how to improve the practice of fire investigation. The Table of Contents of this document is modeled after the National Academy of Science (NAS) report of 2009, *Strengthening Forensic Science in the United States: A Path Forward.*

The executive summary provides the findings and recommendations of the strategic plan on a chapter-by-chapter basis. Chapter 1 is an introduction to the document, Chapters 2 through 5 describe the field of fire and explosion investigation as it is currently practiced, and Chapters 6 through 9 address the changes needed to move the profession forward.

While great progress has been made since the 1980s, there remains much to be done. This strategic plan identifies the work that is needed in the field of fire and explosion investigation in the coming years. The day in which NFPA 1033, NFPA 921, and a fire investigation unit standard (NFPA 1321) are used in an integrated manner by certified fire and explosion investigators with sufficient education in the discipline, working in accredited fire and explosion investigation units, routinely producing high-quality investigations and reports can be envisioned. It remains for the fire investigation community to work toward achieving that end in the coming years.

Chapter 1. Introduction

The writing of this strategic plan was undertaken by the Fire and Explosion Investigation Subcommittee of OSAC after the subcommittee had completed the approval process for inclusion of NFPA 921, *Guide for Fire and Explosion Investigations* (2014), and NFPA 1033, *Standard for Professional Qualifications for Fire Investigator* (2022), on the OSAC Registry of Approved Standards. Subsequently, the 2017 edition of NFPA 921 replaced the 2014 edition on the registry. The subcommittee had also prepared a proposal to NFPA to develop a Standard for the Organization and Operation of Fire and Explosion Investigation Units. This proposal was accepted in 2018, and the committee began its work in 2019. These consensus documents fulfill the basic elements of the quality triangle in forensic science, with NFPA 921 providing the standardization of procedures and practices, NFPA 1033 providing the basis for qualifications and certification of investigators, and the new NFPA standard (NFPA 1321) providing the basis for accreditation of investigation units.

Fire investigation is the process of determining the origin, cause, and development of a fire or explosion. The term fire investigation is widely used to include explosion investigation. Fire investigations involve the analysis of witness and electronic data, fire damage patterns, and fire dynamics. The examination of physical evidence includes the fire scene examination, laboratory analyses of artifacts, and chemical analysis of fire debris. Chemical fire debris analyses are carried out by chemists, while artifact examination and analyses are at times carried out by engineers of varying disciplines, metallurgists, and chemists.

The broader objectives of ascertaining the origin, cause, and development of the fire that fall to the fire investigator are typically more complex than laboratory sample analysis. As the fire grows and consumes combustibles, the complexity of the analysis of chemical and physical aspects of the fire increase while the artifacts that constitute evidence of the origin and cause of the fire continue to be consumed or altered by the fire.

The standardization of methodology is gradually taking place as courts decide that NFPA 921 represents the "standard of care," but many investigators still practice without the benefit of certification. Accreditation of organizations is practically nonexistent in fire investigation.

Judges are called upon to be "gatekeepers" for forensic science evidence. Attorneys need to become better educated in science if they are to have any hope of presenting reliable evidence to juries. It is up to experts in fire investigation to pass their knowledge on to officers of the court through their reports and testimony.

Chapter 2. Current Structure of the Fire and Explosion Investigation Community, and the Need for Integrated Governance

The fire investigation community includes both public and private sector investigators. Public sector fire investigators work for federal, state or local agencies, either law enforcement entities or fire departments. Federally, fire investigation is almost always carried out by the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF). ATF agents are available to assist state and local investigators, and for significant events, ATF's National Response Team can be mobilized. The primary focus of public sector investigators is determining if the cause of the fire or explosion was accidental or the result of a criminal act. Private sector investigators are primarily employed by fire investigative or engineering firms and insurance companies. Private sector fire investigators often are focused on fire causes that relate to product liability, insurance coverage and subrogation. Insurance companies have financial incentives to identify defective equipment or services that are responsible for the cause of the loss. Subrogation litigation is a major driver for the private sector fire investigation business.

Since the first publication of NFPA 921 in 1992, fire investigation began to see an increase in research through a variety of public and private efforts. Since the 2009 NAS Report, there has been an increase in funding of research in fire investigations by the National Institute of Justice (NIJ). Results of fire research are presented in NIJ reports, in journals, at meetings such as the International Association of Arson Investigators (IAAI) Annual Training Conference, and the International Symposium on Fire

Investigation Science and Technology (ISFI). It is expected that the science of fire investigation will be moved forward by this additional research. There are still many areas in fire investigation where there has been little to no research. Additional research is needed to validate forensic methods that assist with origin and cause investigations.

Fire investigators are largely governed by two professional organizations; the IAAI and the National Association of Fire Investigators (NAFI), based on NFPA consensus documents. Both of these organizations offer certification at different levels, and both organizations provide their members with publications directing them to the latest research. Each organization also has a Code of Ethics, to which members must subscribe.

Chapter 3. The Admission of Fire and Explosion Investigation Evidence in Litigation

The admission or exclusion of expert testimony is the responsibility of the trial court judge, the "Gatekeeper." In the years before NFPA 921, there was little effective basis for gatekeeping, even if judges were scientifically literate.

The first edition of NFPA 921 was published just a year before the *Daubert*[1] decision was handed down. Two important court decisions were issued in 1998-1999. In *Michigan Millers Mutual Insurance Corporation v. Benfield,* the Eleventh Circuit ruled that the testimony of the fire science expert was subject to *Daubert* review because the testimony was based on scientific principles, above and beyond experience and skills.[2] In *Kumho Tire Company v. Carmichael,* the U.S. Supreme Court ruled that all expert testimony, not just "scientific" testimony, is subject to a *Daubert* evaluation

1 *Daubert v. Merrell Dow Pharm., Inc.*, 509 U.S. 579, 597, 113 S. Ct. 2786, 2798 (1993)
2 *Michigan Millers Mut. Ins. Corp. v. Benfield*, 140 F.3d 915 (11th Cir. 1998) ("We do not hesitate in finding that Buckley's testimony was science-based, rather than experience-based, and as such is subject to *Daubert* 's inquiry regarding the reliability of such testimony.").

of its relevance and reliability.[3] Thus, in federal cases, fire investigators' testimony was subject to scrutiny under *Daubert* because *Daubert* inquiries on reliability applied to all expert testimony.[4]

In 2000, the IAAI endorsed the adoption of NFPA 921, and the U.S. Department of Justice declared that fire scene examination should be conducted in accordance with NFPA 921. *Daubert* and NFPA 921 in tandem moved fire investigation into the world of forensic science.[5].

NFPA 921 has become deeply entrenched in the post-*Daubert* world of fire litigation, even if courts do not always require that fire investigators testify that they followed it or be able to articulate why they deviated from its guidance.[6]. Although the first two decades of *Daubert* challenges relied on NFPA 921, more direct challenges of the investigator's qualifications

---

[3] *Kumho Tire Co. v. Carmichael*, 526 U.S. 137, 119 S. Ct. 1167, 143 L. Ed. 2d 238 (1999) ("*Daubert's* 'gatekeeping' obligation, requiring an inquiry into both relevance and reliability, applies not only to 'scientific' testimony, but to all expert testimony").

[4] It must be remembered, however, *Kumho Tire* was not adopted by all state courts; thus, in states that have not adopted *Kumho Tire*, expert non-scientific testimony is not subject to *Daubert*. In those states, the relevant question is whether fire science testimony is scientific in nature or non-scientific. For example, in West Virginia fire science testimony is non-scientific and thus not subject to evaluation under *Daubert. See Anstey v. Ballard*, 237 W. Va. 411, 428, 787 S.E.2d 864, 881 (2016) ("Even today, the admissibility of the State's expert testimony would be assessed under Rule 702 of the West Virginia Rules of Evidence as evidence based on technical or specialized knowledge—and not under *Daubert/Wilt*.").

[5] Notably, in *Frye* jurisdictions that have not adopted *Daubert*, NFPA 921 alone acts to demand better science-based investigations.

[6] See, e.g., *Russell v. Whirlpool Corp*., 702 F.3d 450, 455 (8th Cir. 2012) ("We have held NFPA 921 qualifies as a reliable method endorsed by a professional organization, but we have not held NFPA 921 is the only reliable way to investigate a fire. Our NFPA 921 cases stand for the simple proposition an expert who purports to follow NFPA 921 must apply its contents reliably.") (citations and internal quotation marks omitted); *Schlesinger v. United States*, 898 F.Supp.2d 489, 504 (E.D.N.Y. 2012) ("As an initial matter, the Court need not determine whether [the] methodology complied with NFPA 921, because both experts testified that they did not follow NFPA 921 in reaching their conclusions that the fire was incendiary.").

based on NFPA 1033 are likely to become more common. These challenges should result in a more careful vetting of fire investigators proposing to give expert testimony, and an overall improvement in the quality of evidence presented to courts and juries.

Chapter 4. The Principles of Science and Interpreting Scientific Data

The core methodology for fire and explosion investigation has been the scientific method. Drawing on the data (case facts) and knowledge of fire science, the process of recognizing the need, defining the problem, collecting data, analyzing the data, developing hypotheses, testing these hypotheses, and reaching the final hypothesis is iterative, thoroughly documented, and transparent. The structure of the process reduces the potential impact of cognitive biases.

The scientific method is first applied to origin determination and then to cause determination. Along the way, narrower problems subsidiary to the origin and cause determinations are also structured and addressed through the scientific method.

The origin of the fire is the location in three dimensions where the fire started. Initially, the origin is unknown and can be thought of as being indefinite in size and location. The process of hypothesis formulation and testing is one of paring down the volume of the origin by eliminating hypothesized volumes.

The primary interest in determining the origin of the fire is in the service of determining the cause of the fire. The cause determination process requires the formulation of cause hypotheses for all potential ignition sources within the area of origin, as well as identifying the first material ignited, and the ignition sequence. The process of cause determination is simplified by a well-defined area of origin. However, one of the most serious errors an investigator can make is to over-define the area of origin, such that legitimate potential causes are not considered.

Both the origin and cause hypotheses need to be specific so that hypothesis testing is possible. The origin and cause of a fire is determined if one and only one origin and cause hypothesis survives hypothesis testing among all the hypotheses developed.

Investigative errors can arise in data collection, data analysis, development, and testing of hypotheses. Failure to collect sufficient data and misinterpretation of data can cause erroneous findings. Further, the use of biasing irrelevant data can lead to investigative errors. Expectation bias arises when premature conclusions are reached. Confirmation bias arises when investigators lapse into attempts to prove rather than disprove a hypothesis.

In the end, investigators need to be able to articulate the scientific method and demonstrate how it was applied to the investigation. Hypothesis development and testing need to be effectively communicated. Rigorous independent review of the investigation is needed to assure quality work product.

Chapter 5. Descriptions of Some Fire and Explosion Investigation Disciplines

The various tasks within an investigation are set forth by NFPA 1033, Professional Qualifications for Fire Investigator, as Job Performance Requirements (JPR's):

1. Scene Examination
2. Documenting the Scene
3. Evidence Collection/Preservation
4. Interviews
5. Post-Incident Investigation (non-scene)
6. Presentations (written and oral reports, testimony)

The central focus of the scene examination is the identification of the fire effects and patterns of fire effects such as melting, charring, discoloration, etc. The identification of patterns of the fire effects provides the basis for hypothesis development and testing.

In some cases, fire effects and patterns of fire effects can be identified by simple visual observation. In other instances, the identification of individual fire effects requires very close observation and may require measurements or analyses to identify. Visual fire effects are often a combination of multiple fire effects which are not easily separated through simple observation.

Fire scene reconstruction is an important scene examination process. The removal of debris and the establishment of the configuration of objects and fire effects upon these objects can provide significant data and better highlight patterns of fire effects and other contextual data.

Documenting the scene is a central task in fire and explosion investigation, the goal of which is to preserve data for later analysis. Data that is documented include fire patterns, evidence, personnel and processes, structures/vehicles and their systems, and testing. Documentation is typically done through a combination of photography (and photo logs), videography, note-taking, sketching/diagramming, measurements, and audio recording.

Interviews are critical in nearly all fire investigations with interviews of first responders, the fire discoverer(s), occupants, witnesses, property owners and others with information about the property and the event.

Non-scene data is often critical to fire investigations. The non-scene data has a role in defining the timeline of the incident, identifying the area of origin, documenting the growth and spread of the fire, and in providing causation information. Non-scene data should be integrated with scene data for analysis.

The culmination of the documentation of an investigation is typically a written report. The report details the data collected at the scene, physical evidence collected, interviews, and non-scene data. The use of the data to develop and test hypotheses is fully described concerning both origin and cause determinations. The process of hypothesis development and testing needs to be fully explained such that another investigator can evaluate the use of the scientific method to reach conclusions.

Chapter 6. Improving Methods, Practice, and Performance in Fire and Explosion Investigation

A team approach to a fire investigation is more effective than a lone investigator. The need for a team approach has three complementary aspects: 1) safety, 2) the diversity of technical skills required, and 3) the role of collegial interaction.

Working safely on the fire scene requires multiple people. The need for additional investigators grows with the size and complexity of the fire scene. Perhaps most importantly, working as a team in all investigations fosters collaborative investigative work. The collegial interaction of team members can act to minimize individual biases.

There is a need to consider only data that is relevant to the task to guard against presumptions and bias. Relevant data germane to the origin and cause investigation includes information about the fire scene and the actions that occurred at the fire scene either before or during the fire. Task-irrelevant data as it pertains to the origin and cause determinations often relates to motives. Financial, criminal history, social relationship stress, evasive, or deceptive behavior information are not relevant to the determination of the origin or cause of a fire.

The origin and cause analysis needs to be conducted separately from other aspects of the investigation, including determining whether or not a crime has been committed, the potential for insurance fraud, or potential civil litigation. It is sound practice for the fire investigator to only consider data needed for an origin and cause determination. Shielding the fire investigator or a technical reviewer from information not directly relevant to the origin and cause of the fire has been suggested as one way that this can be accomplished.

Reports need to be written in such a way that the process of analyzing data and developing and testing hypotheses is fully explained. In this manner, another investigator can evaluate the use of the scientific method to reach particular origin and cause conclusions. The report needs to identify the hypotheses that survive the testing process and report the findings concerning the fire origin and cause.

An origin and cause report should be technically and administratively reviewed to ensure completeness, clarity, and technical quality. These reviews are a way to identify other potential hypotheses, further test identified hypotheses, and to identify and mitigate bias.

Chapter 7. Research Needs in Fire and Explosion Investigation

Fire investigation, like many other forensic science disciplines, suffers from an inadequate research base. Much of the research conducted into fire phenomena has developed over the last fifty years and was primarily aimed at understanding factors related to fuels and the development of fires in compartments to improve fire safety rather than being focused on determining the origin and cause of fires. There is a need for concerted and focused research programs specifically designed to address the needs of fire and explosion investigation.

This report has enumerated 14 Research Agenda items presented after this executive summary.

Chapter 8. Strengthening Oversight of Fire and Explosion Investigation Practices

Forensic science practitioners, should become certified.

In addition, fire investigators need competency as well as proficiency testing. Competency testing demonstrates the successful completion of a tested training course, while proficiency testing is where the fire investigator's performance is evaluated through their reports, trial/deposition performance, mock reliability hearings, and reviews of investigations by independent third parties. Though not a regular function within most fire investigation units, proficiency evaluation needs to be as common as competency testing.

There is currently no standard suitable for the organization, operation, and accreditation of Fire and Explosion Investigation Units. The OSAC Fire and Explosion Investigation Subcommittee prepared a proposal to NFPA to develop a standard for the organization and operation of fire and explosion investigation units. An NFPA committee has been developed, and committee work on the standard is underway.

It is vitally important that any fire investigation agency be compliant with best practices. Accreditation is an important component of validating that an agency is assuring that their investigators meet NFPA 1033 requirements and investigating fires according to NFPA 921. An accreditation process creates an environment of continuous improvement based on national consensus standard best practices. It is the OSAC Fire and Explosion Subcommittee's vision that in time, accreditation will become the norm in fire investigation units.

Innovations are needed to move forward with quality improvements. The Science Advisory Workgroup (SAW) as developed by the Texas State Fire Marshal's Office (SFMO) is one recent innovation that represents a model available to other states and jurisdictions. The Texas SAW provides training to fire investigators and conducts retrospective case reviews to help the SFMO investigators become increasingly proficient.

Chapter 9. Education and Training in Fire and Explosion Investigation

Fire investigation is a recognized forensic science discipline that requires a high level of procedural knowledge as well as a working understanding of a variety of traditional scientific and engineering subjects. A major challenge to educating fire investigators is that most had little or no scientific education before entering the field.

The qualification requirements for fire investigators are defined in NFPA 1033: *Standard for Professional Qualifications for Fire Investigator*. Notably, the minimum education required by NFPA 1033 is a high school diploma. It is generally accepted that knowledge of scientific and engineering concepts is necessary to produce accurate determinations of the origin and cause of fires. A high school diploma does not guarantee any significant background in science.

NFPA 1033 also requires that investigators have and maintain at a minimum an up-to-date basic knowledge of 16 technical topics beyond the high school level. The OSAC subcommittee on Fire and Explosion Investigations recommends that the 16 topics should be reorganized and the level of knowledge and proficiency that investigators need in the topic areas should be more precisely defined.

While many training opportunities exist for fire investigators, there are minimal educational programs available. Only three (3) universities in the United States currently provide degree programs specific to fire investigation.

For fire investigators to understand the scientific aspects of the profession, they should have a working knowledge of the following topics: mathematics, chemistry, heat transfer, thermodynamics, fire dynamics, and electrical wiring theory and practice. Ideally, this knowledge would be acquired through coursework at an accredited academic institution. Additional degree programs specific to fire investigation should be designed and implemented at other institutions around the United States. A curriculum specific to fire investigation should be integrated into closely related fields of study to assist with those entering the field from other engineering and physical science degree programs.

Most fire investigators have limited experience testifying in court, and the first time that many investigators are subjected to a challenging review of their work is when an investigation is going to court. This has the potential of impacting court outcomes. Mock *Daubert* motions and trials should be used in training programs to provide investigators the opportunity to better prepare for such hearings.

New training and proficiency testing programs should be implemented to assure that fire investigators have the skills and knowledge to come to the correct conclusion about the causes of fires.

Chapter 10. Conclusions

The first edition of NFPA 921 was published in 1992. Much progress has been made since this early recognition of the need to enhance the practice of fire and explosion investigation. The field of fire and explosion investigation can now be said to be in its adolescence, but much work is required to bring it to maturity.

In terms of the impact of NFPA 921 on fire-related litigation, progress has been far more rapid in civil litigation than in criminal matters. Judges and lawyers need to be educated and trained on fire science and investigation to assure that only reliable fire investigations and analyses are presented to juries.

NFPA 1033 has taken its place in defining the qualifications of fire and explosion investigators. The continuing development of NFPA 1033 is needed to support continuing improvements in fire investigation.

It has become clear that the current NFPA 1033 educational requirement of a high school degree can no longer be accepted. The 16 knowledge areas which bear on fire and explosion investigation are too sophisticated for investigators to master the needed science and technology working simply from a high school education. Fire is a collection of complex physical and chemical processes that necessitates investigation by those educated in the science and practice of fire and explosion investigation. The day when a BS in one of the physical sciences, engineering, or fire and explosion investigation is the entry-level educational requirement needs to be realized in the coming years.

The field of fire and explosion investigation needs to move toward accreditation of all fire and explosion investigation units. In 2016, the OSAC Fire and Explosion Investigation Subcommittee proposed that NFPA develop a Standard on the Organization and Operation of Fire Investigation Units. That proposal was accepted, a technical committee was formed, and a proposed draft of the standard was submitted to NFPA. This standard should provide a foundation for accreditation of fire and explosion investigation units.

Fire and explosion investigation units need to implement information management practices to minimize bias and reduce exposure to task-irrelevant data. Also, there is a need for fire investigation units to fully implement the scientific method and technical review processes to minimize potential bias. All stakeholders need to take responsibility for requiring complete and comprehensive fire and explosion investigation reports.

Sustained funding for fire and explosion investigation research is needed to move the discipline forward. The research agenda detailed in Chapter 7 needs to be implemented. Efforts are required to assure that research for fire investigation is easily accessed by investigators.

RECOMMENDATIONS

The following recommendations will require advocacy from all fire and explosion investigation stakeholders. The identified stakeholders are those who need to take direct action to achieve the recommendation.

Chapter 6: IMPROVING METHODS, PRACTICE, AND PERFORMANCE IN FIRE AND EXPLOSION INVESTIGATION

Recommendation*: Fire and explosion investigation units should operate using a team approach. Cooperative investigation task force arrangements with neighboring jurisdictions, with state-level agencies, and with ATF should be organized and supported*.
Stakeholders: FIU Managers, NFPA 1321 Committee, Accreditation Bodies

Recommendation*: Fire and explosion investigation units should implement information management practices to minimize bias.*
Stakeholders: FIU Managers, NFPA 1321 Committee, Accreditation Bodies

Recommendation*: Fire and explosion investigation units should implement practices to minimize potential bias by using such processes as rigorous adherence to the scientific method*[7]*, a technical review process, and processes to limit the exposure of investigators to biasing information.*
Stakeholders: FIU Managers, NFPA 1321 Committee, Accreditation Bodies

Recommendation*: Fire and explosion investigation reports should include all data collected, all hypotheses formulated, details of the testing process for each hypothesis, and the conclusions of the investigation.*

---

[7] NFPA 921 defines the scientific method as "The systematic pursuit of knowledge involving the recognition and definition of a problem; the collection of data through observation and experimentation; analysis of the data; the formulation, evaluation and testing of hypotheses; and, where possible, the selection of a final hypothesis."

Stakeholders: Investigators, FIU Managers, Certification and Accreditation Bodies, NFPA 1321 and 921 Committees

Recommendation: *All stakeholders (investigators, managers, lawyers, judges, insurance companies) must take responsibility for requiring complete and comprehensive fire and explosion investigation reports.*
Stakeholders: Investigators, FIU Managers, Lawyers, Judges, Insurance Companies, Investigator Professional Associations, Certification and Accreditation Bodies, NFPA 921, 1033, and 1321 Committees, Educators

Chapter 7: RESEARCH NEEDS IN FIRE AND EXPLOSION INVESTIGATION

Recommendation: *The Research Agenda developed below should be adopted by research funding agencies and should be carried out over the next several years.*
Stakeholders: Fire Research Community

Chapter 8: STRENGTHENING OVERSIGHT OF FIRE AND EXPLOSION INVESTIGATION PRACTICES

Recommendation: *Require competency and proficiency testing for fire investigation units both in their training and their continued monitoring of their work product.*
Stakeholders: FIU Managers, Accreditation Bodies, NFPA 1321 Committee, Educators

Recommendation: *Require accreditation of fire investigation units by third parties based on an applicable consensus standard.*
Stakeholders: NFPA 1321 Committee, Accreditation Bodies

Recommendation: *Require case reviews be developed and implemented, which can include retrospective and proactive reviews. A multi-disciplinary review committee can be used to assist with this process, such as the one implemented by Texas SFMO.*

Stakeholders: FIU Managers, NFPA 1321 Committee, Accreditation Bodies

Recommendation: *Require fire investigation units to adopt a quality assurance system.*
Stakeholders: FIU Managers, NFPA 1321 Committee, Accreditation Bodies

Recommendation: *Require all fire investigation reports to be subject to technical and administrative reviews. Require that case documentation supports the opinions within the report.*
Stakeholders: FIU Managers, NFPA 1321 Committee, Accreditation Bodies

Recommendation*: Develop a consensus standard for the organization and operation of a fire and explosion investigation unit.*
Stakeholders: NFPA 1321 Committee

Recommendation: *Require fire investigation units to adopt a Code of Ethics.*
Stakeholders: FIU Managers, NFPA 1321 Committee, Accreditation Bodies

Chapter 9: EDUCATION AND TRAINING IN FIRE AND EXPLOSION INVESTIGATION

Recommendation*: Fire investigators should complete college-level coursework in algebra, chemistry, and physics, and understand how these subjects relate to the behavior of fire.*
Stakeholders: Investigators, FIU Managers, Certification and Accreditation Bodies, NFPA 1033 and 1321 Committees, Educators

Recommendation*: Fire investigation units should establish a formal process for fire investigators' work to be subjected to challenging technical review. This system should include both a review of written investigation records and reports as well as a verbal review that simulates testimony in depositions and trials. Investigators should be required to submit their work to this process routinely.*

Stakeholders: FIU Managers, NFPA 1321 Committee, Accreditation Bodies

Recommendation*: Fire Investigation Units should be required to establish a program that provides sufficient training and continuing education for fire investigators to meet the knowledge and Job Performance Requirements of NFPA 1033.*
Stakeholders: FIU Managers, NFPA 1321 Committee, Certification and Accreditation Bodies, Educators

Recommendation*: Continuing education should be mandatory with a requirement for proof that an investigator is learning up to date information and reliably apply this information in the context of the scientific method.*
Stakeholders: Investigators, FIU Managers, Certification and Accreditation Bodies, Educators

Recommendation*: More competency and proficiency training and testing focused on specific knowledge and skills should be developed for fire investigations.*
Stakeholders: Educators, Fire Research Community, Certification Bodies

1 INTRODUCTION

1-1 Introduction

This report sets out the strategic vision for the improvement of fire and explosion investigation in the United States. The first five chapters review various aspects of the field as it currently exists. The remaining chapters develop recommendations and a research agenda to move the profession forward. It was prepared by the Fire and Explosion Investigation Subcommittee of the Organization of Scientific Area Committees (OSAC).[8] The scope of the report mirrors the scope of the profession of fire and explosion investigation as described in NFPA 921, *Guide for Fire and Explosion Investigations*, and NFPA 1033, *Standard for Professional Qualifications for Fire Investigator*. This strategic plan is a response to the National Academy of Sciences (NAS) 2009 report, *"Strengthening Forensic Science in the United States: A Path Forward."* [NAS 2009].

One thing the NAS report made unequivocally clear was that **fire investigation is a forensic science**. Although there are still some practitioners who resist the label of forensic scientist, a body of law has developed around the premise that fire and explosion investigation should be conducted according to the scientific method as set forth in NFPA 921, *Guide for Fire and Explosion Investigations* [NFPA 921].

This strategic plan is an analysis of where the fire investigation profession is now, where it should be, and what steps should be taken to get to the level needed. The first of these steps have already been taken by the OSAC in moving NFPA 921, *Guide for Fire and Explosion Investigations*, and NFPA 1033, *Standard for Professional Qualifications for Fire Investigator* onto the OSAC Registry of Standards. Inclusion on the Registry indicates that the

---

[8] The Fire and Explosion Investigation Subcommittee focuses on identifying and improving standards, guidelines and best practices for conducting investigations and presenting results, identifying research needs, and proposing strategies for increasing the reliability of investigative determinations.

documents are American National Standards Institute (ANSI) consensus standards that are well accepted by the fire and explosion investigation community and have met the standards of quality to be included in the Registry.

Having reviewed NFPA 921 and NFPA 1033, the subcommittee began to examine broader aspects of fire investigation and how investigations are conducted, guided in part by the NAS report. While the NAS report provided a roadmap for forensic science generally, the report did not focus on fire and explosion investigation. Others, like the American Association for the Advancement of Science, have reviewed the state of fire investigation and identified gaps that require filling [Almirall et al. 2017]. The goal of this strategic plan is to apply the breadth and depth of the NAS report on forensic science to fire and explosion investigation more specifically. This report provides challenges to all the various stakeholders in fire investigation and to the profession as a whole that will require many years to overcome.

1-2 What is Fire and Explosion Investigation?

NFPA 921 [2021] defines fire investigation as "the process of determining the origin, cause, and development of a fire or explosion."

The examination of physical evidence in fire and explosion investigation includes three basic types of analyses -- fire scene investigation, laboratory analysis of artifacts and fire debris analysis. While fire scene investigation occurs primarily at the scene, laboratory analysis of artifacts and fire debris analysis primarily occur in a laboratory setting for identification and evaluation of potential fire causes or detecting and identifying ignitable liquid residues (ILRs). Fire scene investigation, artifacts analysis, and fire debris analysis are most often carried out by completely different cadres of practitioners. The laboratory analysts are usually physical scientists with college degrees, while the fire scene investigators' level of education and training varies widely. Currently, the standard requirements to qualify as a fire investigator include a high school diploma and knowledge of certain topics related to fire investigation "beyond the high school level." [NFPA 1033 [2022] §1.3.7]

Fire scene investigation is very challenging for several reasons, such as the extensive destruction of evidence caused by the fire and firefighting activities, the complex behavior of fire, and the inadequate understanding of fire chemistry and physics by some investigators. Some of the evaluations and determinations made by fire investigators are based on subjective determinations and judgments and, hence, depend on human cognitive factors. Depending on the extent of damage, one of a fire investigator's most difficult tasks is determining the fire's point of origin.

> *"The origin of a fire is one of the most important hypotheses that an investigator develops and tests during the investigation. Generally, if the origin cannot be determined, the cause cannot be determined, and generally, if the correct origin is not identified, the subsequent cause determination will also be incorrect"* [NFPA 921(2021) §18.1].

Fire investigation involves the evaluation of numerous factors, including witness statements, fire patterns, and fire dynamics. Analyzing these factors and documenting the relevant evidence is essential to understanding where the fire began, how and why it grew, and what caused the fire to start. It is also important for fire investigators to document any actions taken by firefighters that may have altered the scene and evidence so that it can be taken into account when conducting the investigation.

Investigators must understand the relationship between the elements of the fire tetrahedron: heat, fuel, oxygen, and a sustained chemical reaction. Although fire investigations are complex because of the different variables to be considered, fires follow predictable behaviors. Initially, flames and smoke tend to flow up and outwards in a three-dimensional buoyant plume rising from the fire. In a room (often called a compartment or enclosure), these hot gases rise to the ceiling and then expand downward to form a smoke layer, charring or discoloring anything in this hot upper layer of the room. Patterns on surfaces in the fire enclosure will demonstrate how far the hot gases extended down from the ceiling. These behaviors leave behind patterns of damage that, *if interpreted correctly*, allow fire investigators to determine how the fire progressed through the structure, the fuels involved, and the origin. Correctly interpreting fire patterns, however, is challenging. [Carman 2008]

Burn patterns may be confusing and misleading because the origin will not necessarily be located where observable damage is most severe. This is particularly true for enclosure fires that grow to the point of full-room involvement. Full-room involvement (FRI) means that combustion is occurring throughout the room, though not at the same rate throughout. Typically, all exposed combustibles in the room are pyrolyzing to produce fuel gases which burn as a flame upon mixing with oxygen. Full room involvement generally leads to "ventilation-limited" burning, which means the rate of burning of the fuel gases within the room becomes limited by the inflow rate of air into the enclosure through ventilation pathways rather than being limited by the rate of fuel gases released by burning surfaces.

In a fully involved enclosure fire, the most intense burning occurs where fuel vapors encounter oxygen entering the fire enclosure, and that may not be where the fire originated. Such ventilation-generated burn patterns have been interpreted incorrectly in the past and are the subject of ongoing interest and research in the fire investigation community. Such misinterpretations have included inaccurate findings regarding the use of ignitable liquids and multiple fire origins, leading to incorrect determinations that fires are intentionally set (incendiary).

Before making any determinations concerning the burn patterns, some factors that should be considered include analyzing damage to identify rooms which have become fully involved, analyzing the effects of ventilation, fire suppression effects, and the effects of "drop down" and structural collapse. After all the parameters are considered, and current understanding of their effects are applied, the investigator may be able to use them to form a hypothesis as to the area of origin, the spread of the fire, the time for development, and the heat generated during the fire.

Explosion investigation differs from fire investigation in that unless there is a major fire after the initial explosion, the event is quite brief. NFPA 921 defines an *explosion* as "the sudden conversion of potential energy (chemical or mechanical) into kinetic energy with the production and release of gases under pressure or the release of gas under pressure. These high-pressure gases then do mechanical work such as moving, changing, or shattering nearby materials." An *explosive* is defined as "Any chemical compound, mixture, or device that functions by explosion."

There are some explosions that are the result of criminal activity. These are usually investigated by federal authorities. Explosions that happen in a residential context are generally the result of the ignition of fuel/air mixtures.

Explosions can be classified as mechanical, boiling liquid expanding vapor explosions (BLEVE), chemical, electrical, and nuclear. Nuclear explosions are well outside of the scope of this document. Explosion damage can be classified as *low order damage*, characterized by walls bulged out or laying down intact, or lifting of roofs; or as *high order damage* characterized by shattering of the structure, producing debris pieces. The documentation of explosion damage is generally similar to the documentation of fire damage. NFPA 921 contains an entire chapter devoted to the analysis of explosion damage. [NFPA 921 [2021] in Chapter 22]

At this time, forensic fire debris analysis in the laboratory focuses on the presence and classification of ignitable liquids, a process based on established scientific principles. Characterization of the ignitable liquid residues (ILR) is often difficult because of the liquid's exposure to the heat of the fire. The validity and reliability of fire debris analysis have been established through organized efforts within the discipline. The chemical analysis and interpretation of forensic evidence from fire debris have benefitted from a coordinated volunteer effort to develop and continuously improve analytical standards. Advancements in analytical methodology have driven the improvements in these standards (e.g., adoption of gas chromatography coupled with mass spectrometry (GC-MS) as opposed to gas chromatography (GC) alone). Despite the progress made, there is still work to be done. The changing nature of ignitable liquids, such as gasoline composition and our understanding of ILRs, necessitates the continued refinement of these analytical standards.

1-3 Challenges to the Fire and Explosion Investigation Profession

A central thrust of the NAS Report is the call for mandatory certification of individuals, mandatory accreditation of organizations, and mandatory standardization of methodology. The National Commission on Forensic Science (NCFS) [2017] also provided calls for certification, accreditation, and standardization. Like most forensic sciences, fire investigation has no mandatory requirements for any of these. The standardization of methodology is gradually taking place as courts decide that NFPA 921 represents the "standard of care," but the practitioners, who may be forced to follow NFPA 921 if they want their opinions admitted into evidence, are still allowed to practice without the benefit of certification. Accreditation of organizations is practically nonexistent in fire investigation with only four organizations having been accredited by the end of 2020.

Studies [Tinsley and Gorbett 2012, Cook 2015] have shown that current certification requirements do not demonstrably improve the practice of fire investigation. We need to make certification relevant to high standards of investigation performance and encourage the institutionalization of requirements for certification.

Fire investigator certification is available from individual states and at least one federal organization; however, these apply only to the employees of these certifying bodies, and certification by one's employer is not the same as a third-party certification. Third-party certification is offered by the International Association of Arson Investigators (IAAI), and by the National Association of Fire Investigators (NAFI). Each of these organizations offers several different types of certification. However, certification is not mandatory.

As a forensic science discipline, fire investigation is challenged by the amount of widespread, persistent, and problematic myths affecting the beliefs and the behavior of its practitioners [Lentini 2006]. As long ago as

1977, Boudreau, Kwan, and Faragher, working on an Aerospace Corporation grant from the Law Enforcement Assistance Administration (LEAA), conducted a "Survey and Assessment" of arson and arson investigation techniques. In that assessment, the authors listed seven "burn indicators," but stated, "Although burn indicators are widely used to establish the causes of fires, they have received little or no scientific testing." They recommended "that a program of carefully planned scientific experiments be conducted to establish the reliability of currently used burn indicators," and "a handbook based on the results of the testing program should be prepared for field use by arson investigators" [Boudreau et al. 1977].

Three years later, the *Fire Investigation Handbook* was published by the National Bureau of Standards (NBS). Unfortunately, the "scientific studies" recommended in 1977 had not been conducted, and the handbook repeated most of the myths that had been used to incorrectly determine that an arson fire burned faster or hotter than normal. One of the goals of NFPA 921, which was first published in 1992, was debunking the existing nonscientific myths. Lentini [2006] documents and explores the development, publication, and eventual debunking of many arson myths.

Over the past three decades, much has been learned about fire behavior and investigation, but the distribution of the knowledge among field investigators has not been uniform [Tinsley and Gorbett 2012]. The most important knowledge, which was often used to distinguish between incendiary fire causes and accidental fire causes in the past, can be briefly summarized as follows:

- The evidence left behind by fully involved accidental fires is often indistinguishable from evidence left by fully involved incendiary fires [Putorti 1997]. Artifacts once thought to indicate incendiarism but now known to be of little value in determining the cause of fires include: downward burning; charring of floors and baseboards; charring on the undersides of surfaces; large shiny char blisters; irregular fire patterns; melted metals; crazed glass; and spalled concrete [Lentini 2006].

- The speed with which a fire spreads in modern residences is not ordinarily a data point that can be used alone to determine the cause of the fire. Modern furnishings, particularly upholstered furniture made with polyurethane or polyester fiberfill cushions, can burn so quickly as to cause a room to become fully engulfed in flames in less than five minutes. Modern furnishings are in contrast to "legacy" furnishings made with cotton and wood, which burn with much lower intensity [Kerber 2012, UL 2015].

- The behavior of fires under differing ventilation conditions, unless well understood, can lead to erroneous determinations of the origin and cause of the fire. The ventilation (oxygen) available to a fire is largely responsible for the behavior of a ventilation-limited fire, including its temperature. In ventilation-limited fires, the amount and the flow path of available oxygen determine how severely a fire will burn at a particular location. In ventilation-limited fires, fuel vapors move away from the fuel source and burn near ventilation openings where they mix with the incoming oxygen. This will cause ventilation-generated burn patterns, remote from the area of origin, that need to be taken into account during an investigation.

- For fully developed fires, it is more difficult for fire investigators to correctly determine the area(s) of origin based only on interpreting fire patterns, and the level of difficulty increases the longer a fire burns in a fully involved condition [Cox 2013]. Research conducted since 2005 reveals that in some cases, the ability of a fire investigator to determine the correct area of origin in a fully involved room by only interpreting fire patterns may be no better than random chance [Carman 2008, Heenan 2010]. Tinsley and Gorbett's 2012 study showed 22-26% erroneous conclusions when 587 self-selected investigators, working independently, viewed photos and data from a fire that burned for one minute beyond flashover. These results were similar to the 31% erroneous conclusions found in a 70-second–beyond-flashover study conducted in 2007 [Heenan 2010].

Another challenge to the accurate presentation of fire investigation evidence in court is the lack of appreciation on the part of lawyers and judges for the lack of expertise of some in the fire investigation community. Judges are called upon to be "gatekeepers" for forensic science evidence, but generally are reluctant to exclude expert testimony, for fear of being overturned on appeal, even though the standard of review, "abuse of discretion" is very deferential. This reluctance is especially present in the criminal courts, where judges are reluctant to exclude forensic science witnesses. Exclusions are much more common in civil cases, where both sides tend to have more resources than the average criminal defendant [NAS 2009 p. S-8].

Responding to the challenges of fire investigation requires resources, and the availability of resources is not close to uniform. Federal agencies typically have better resources than state and local agencies, but no agencies seem to have enough. Resources could also be applied to salaries so that fire investigation agencies could attract better-educated applicants. Improving the quality of the applicant pool cannot be done with the resources currently available for personnel.

REFERENCES

Almirall, J., Arkes H., , Lentini, J., Mowrer, F., and Pawliszyn, J. (2017), Forensic Science Assessments: A Quality and Gap Analysis Fire Investigation, American Association for the Advancement of Science, DOI: 10.1126/srhrl.aag2872, https://www.aaas.org/sites/default/files/reports/Fire%20Investigation.pdf

Boudreau J.F. et al. (1977). *Arson and Arson Investigation: Survey and Assessment*. Law Enforcement Assistance Administration (LEAA), U.S. Department of Justice, pp.1-132. https://www.ncjrs.gov/pdffiles1/Digitization/147389NCJRS.pdf

Brannigan F.L., Bright R.G., and Jason N.H. (1980). *Fire Investigation Handbook*, National Bureau of Standards Handbook 134, Washington, DC: US Government Printing Office. (out of print) https://www.ojp.gov/pdffiles1/Digitization/73598NCJRS.pdf

Carman, S. (2008). Improving the Understanding of Post-Flashover Fire Behavior. *Proceedings of the 3rd International Symposium on Fire Investigations Science and Technology* (ISFI), NAFI, Sarasota, FL. http://www.carmanfireinvestigations.com/

Cook, D.E. (2015) *Have We Learned The Lessons Of The Willingham Case?,* A National Survey Of Fire Investigators, A Research Project Submitted To National University in Partial Fulfillment of The Requirements for the Degree of Master Of Forensic Sciences. http://www.forensicresearchdigest.com/yahoo_site_admin/assets/docs/Cook_-_Thesis_FINAL_DRAFT_-_AS_BOUND.259175111.pdf

Cox, A. (2013). Origin Matrix Analysis: A Systematic Methodology for the Assessment and Interpretation of Compartment Fire Damage. *Fire and Arson Investigator Journal*, International Association of Arson Investigators, Vol. 64, pp. 37-47

Heenan D. (2010). History of the Post Flashover Ventilation Study. Presentation made at CAAI, November 2010. https://app.box.com/s/rzychcvtdjm738ns3ko7ou69fayjd4xy

Kerber, S. (2012) Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes, *Fire Technology*, 48: 865. doi:10.1007/s10694-011-0249-2. https://doi.org/10.1007/s10694-011-0249-2

Lentini J. (2006), The Mythology of Arson Investigation, in *Proceedings of the 2nd International Symposium on Fire Investigations Science and Technology* (ISFI), NAFI, Sarasota, FL. https://drive.google.com/drive/folders/1d_V2v8q8fkWAmsxCD3icf6Qi-LYziR47

National Academy of Sciences (2009), Committee on Identifying the Needs of the Forensic Sciences Community; Committee on Applied and Theoretical Statistics, National Research Council, *Strengthening Forensic*

Science in the United States: A Path Forward. https://www.ncjrs.gov/pdffiles1/nij/grants/228091.pdf

National Commission on Forensic Science (2017), Work Products of the FCFS, https://www.justice.gov/archives/ncfs/work-products-adopted-commission

NFPA 921: *Guide for Fire and Explosion Investigations*, 2021 edition, NFPA, Quincy, MA. http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=921

NFPA 1033: *Standard for Professional Qualifications for Fire Investigator*, 2022 edition. NFPA, Quincy, MA. http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=1033

Putorti A. (1997), Full Scale Room Burn Pattern Study. NIJ Report 601-97, National Institute of Justice, Washington, D.C., December 1997. https://www.nist.gov/publications/full-scale-room-burn-pattern-study-nij-report-601-97

Texas SB 1287 (2015) http://www.fsc.texas.gov/texas-forensic-science-commission-forensic-analyst-licensing-program

Tinsley A.T. and Gorbett G.E. (2012), Fire Investigation Origin Determination Survey. *International Symposium on Fire Investigation Science and Technology* (ISFI), pp. 53-68. https://ssem.eku.edu/sites/ssem.eku.edu/files/files/Gorbett%20-%20FIRE%20INVESTIGATION%20ORIGIN%20DETERMINATION.pdf

Underwriters Laboratories. (2015), *Modern Residential Fires*. https://ulfirefightersafety.org/research-projects/comparison-of-modern-and-legacy-home-furnishings.html

2. CURRENT STRUCTURE OF THE FIRE AND EXPLOSION INVESTIGATION COMMUNITY, AND THE NEED FOR INTEGRATED GOVERNANCE.

2-1 Introduction

The fire investigation community consists of public sector and private sector individuals who either investigate fire scenes to determine the origin and cause or review the work of others who have made such determinations. These individuals are aided in these efforts by a broad array of experts in other disciplines.

Most public sector fire investigators work for either state or local agencies. Some of these are law enforcement positions, and some are under the fire department without law-enforcement powers. In such cases, the fire department personnel make their determinations, and then, if criminal activity is indicated, they turn their reports over to law enforcement. In court proceedings, the fire investigator often serves as the prosecution's chief witness.

In the federal system, fire investigation is almost always carried out by the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF). ATF agents are available to assist state and local investigators, and in the case of a significant fire or explosion, ATF's National Response Team can be mobilized to focus numerous personnel and other resources to a site.

Public sector investigators are typically tasked with determining whether a fire was the result of a criminal or unintentional act. In many instances, once a fire has been determined to be the result of a non-criminal event, the public sector investigators withdraw, leaving any additional investigation to the private sector.

Private sector investigators are employed by fire investigative or engineering firms and insurance companies. They are engaged by insurance companies, manufacturers, attorneys, or public agencies to investigate fire origin and cause. These investigators' roles may vary depending upon whom they are engaged by and the purpose of the investigation. The investigator may be asked to address issues related to insurance coverage, issues arising out of subrogation involving a manufacturer's product, or assisting a public agency in dealing with a specific need associated with their investigation.

Both public and private sector investigators rely on chemists to analyze fire debris to determine the presence of ignitable liquid residues. Criminal prosecutions or denials of insurance proceeds are likely to follow if gasoline or other ignitable liquid residues are detected in places where they do not belong. Chemists also can assist in the identification of substances such as vegetable oils that are capable of undergoing spontaneous combustion (e.g., oil-soaked rags), comparing ignitable liquid residues with potential sources, analysis of explosives and general substance identification.

Investigators may rely on engineers when evaluating many factors relevant to understanding a fire event. Engineers evaluate electrical and mechanical devices to determine if they could be potential ignition sources. Engineers evaluate fire protection and signaling systems to determine the role that they played during a fire. Engineers calculate the movement of heat and smoke through structures, calculate the dispersion of flammable and toxic gases in leak scenarios, and calculate radiant heat transfer which may lead to ignition of items remote from the initial fire source.

In addition to the determination of whether coverage is available or appropriate, insurance companies also have a strong incentive to determine the cause of an accidental fire, which may have been caused (or exacerbated) by someone other than their insured. For example, if a defective appliance can be shown to have caused a fire, that may prompt the insurance company to seek reimbursement, through subrogation, from the manufacturer of that product. The same applies to service providers such as architects, electricians, fire protection system designers and installers, roofers, welders, or anyone else who has provided a service in a negligent (or allegedly negligent) fashion that caused a fire. These potential defendants often have liability insurance, and their insurance carriers may retain additional fire investigation professionals. Subrogation litigation is a major driver for the private sector fire investigation business. Fire-related civil litigation not driven by subrogation frequently involves claims of personal injury or wrongful death.

It is in the context of subrogation litigation (or potential litigation) that engineers such as mechanical engineers and electrical engineers are often brought into a fire investigation. Engineers may also be brought in to assess certain potential accidental causes.

2-2 Oversight

In the public sector, government entities that receive federal funds for criminal investigations, including crime laboratories and fire marshal's offices, are required to have in place a "Coverdell entity." This entity is named for the Paul Coverdell National Forensic Sciences Improvement Act of 2000 [Public Law 106-561], which governs the provision of grant money (Coverdell grants) to various agencies. Under the Justice for All Act of 2004 [Public Law 108-405], agencies applying for Coverdell Program grants are required to certify that a government entity exists and appropriate processes are in place to conduct independent external investigations into allegations of serious negligence or misconduct substantially affecting the integrity of forensic results.

Some states have "forensic science commissions" to serve this function, but the function is also carried out in some places by Internal Affairs Divisions or an Office of Inspector General. The extent and rigor of oversight by Coverdell entities vary widely depending on the jurisdiction. More information on the Coverdell Program is available from the National Institute of Justice (NIJ) website.

The Texas Forensic Science Commission (TX FSC) is an example of a Coverdell entity that maintains a rigorous focus on its mission. The TX FSC has investigated numerous claims of problems with arson investigations and in 2011 issued a 17-item list of recommendations for the conduct of public sector fire investigations and prosecutions. They have also examined allegations of problems with bite mark comparisons, DNA mixture issues, bloodstain pattern analysis problems, and microscopic hair comparisons.

2-3 Licensing

In most states, private-sector fire investigators (PIs) are required by law to register and pay fees as private investigators. Law enforcement officials are exempt from such requirements, and there are a few states that exempt "forensic experts" from their private investigation law. There are numerous provisions with many PI laws, depending on the state, which may provide exemptions to these PI licensing requirements. In some states, in addition to holding a PI license, the individual investigator may also be required to be certified as a fire investigator. As of 2017, only five states (Alaska, Idaho, Mississippi, South Dakota, and Wyoming) do not require private investigators to be licensed.

2-4 Research

Since the first publication of NFPA 921 in 1992, fire investigation began to see an increase in research through a variety of public and private efforts. Some of the federal funding for this research was offered through NIJ and NIST [Shanley et al. 1997, Putorti 1997, Madrzykowski 2000]. NIST's Building Fire Research Laboratory published much of their ignition and heat release rate data through an online database that was useful to fire investigators. However, this database is no longer available.

Since the 2009 NAS Report, wherein fire investigation was identified as a forensic science discipline, there has been an increase in funding of research in fire investigations. NIJ has funded much of the recent work (https://www.nij.gov/topics/law-enforcement/investigations/fire-arson/pages/welcome.aspx). Recent research has included an examination of the Forensic Analysis of Ignitable Liquid Fuel Fires in Buildings [Mealy, Wolfe & Gottuk 2013]. Other projects have involved collaboration between outside contractors and the ATF Fire Research Laboratory (FRL) in Ammendale, MD. In 2016, Underwriters Laboratories (UL) embarked on a research program funded by NIJ to study the effects of ventilation on both firefighter safety and fire pattern production.

Results of fire research are presented in NIJ reports, in peer-reviewed fire journals (e.g., *Fire Technology*), at meetings such as the Fire and Materials Conference, the IAAI's Annual Training Conference, the International Symposium on Fire Investigation Science and Technology (ISFI), and in *Fire and Arson Investigator*, the official Journal of the IAAI.

It is expected that the science of fire investigation will be moved forward by this additional research. Research conducted by public or private entities, particularly when done for a specific investigation, may not be published. Despite the research thus far, there are still many areas in fire investigation where there has been little to no research. Additional research is needed to validate forensic methods that assist with origin and cause. Current research needs are identified in Chapter 7.

2-5 Governance

Except for cases in which a Court decides whether a fire investigator will be allowed to render opinion testimony, fire investigators are largely governed by two professional organizations. The International Association of Arson Investigators (IAAI) founded in 1949, now has over 10,000 members, of whom more than 2,000 are certified. The National Association of Fire Investigators (NAFI), founded in 1961, has over 6,500 members, of whom more than 5,000 are certified. Both of these organizations offer certification at different levels, and both organizations provide their members with publications directing them to the latest research. Each organization also has a code of ethics, to which members must subscribe.

Table 2-1. Certification available to fire investigators in 2018.

Designation	Organization	2017 Cost (USD)	Comment
Certified Fire Investigator (CFI)	IAAI	195 (member) 570 (non-member)	
Fire Investigation Technician (FIT)	IAAI	90 (member) 325 (non-member)	
Evidence Collection Technician (ECT)	IAAI	280 (member) 490 (non-member)	
Certified Instructor (CI)	IAAI	150 (member) 395 (non-member)	
Certified Fire & Explosion Investigator (CFEI)	NAFI	125 (members only)	
Certified Vehicle Fire Investigator (CVFI)	NAFI	125 (Members only)	Requires course completion. Cost >700
Certified Fire Investigation Instructor (CFII)	NAFI	75-125 (depends on course completed, members only)	Requires course completion. Cost >700
Certified Fire Investigator (CFI)	ATF	N/A	Available to ATF Special Agents only
Certified Fraud Examiner (CFE)	Association of Certified Fraud Examiners (ACFE)	400 (members only)	Must join ACFE
Certified Insurance Fraud Investigator (CIFI)	International Association of Special	200 (member) 400 (non-member)	

	Investigation Units (IASIU)		
Certified Insurance Fraud Analyst (CIFA)	IASIU	200 (members only)	Annual dues 80
Certified Fire Protection Specialists (CFPS)	National Fire Protection Association (NFPA)	350 + 125/year	Work and education requirements
Various	State Agencies	N/A	Employer based

In December 2016, the National Commission on Forensic Science (NCFS) approved a document entitled "Views of the Commission: Accreditation of Forensic Science Certification Bodies." The document [NCFS 2016] states,

> *"It is the view of the Commission that certification bodies should:*
>
> - *Seek compliance to ISO/IEC 17024 Conformity Assessment – General Requirements for Bodies Operating Certification of Persons. This process should be accomplished within 10 years of implementation.*
> - *Be accredited in accordance with the requirements of ISO/IEC 17024 by an accreditation body operating in accordance with ISO/IEC 17011 – General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies and signatory to the International Accreditation Forum (IAF) Multilateral Arrangement (MLA).*
> - *Collaborate with other certification bodies to develop uniform certification requirements.*
> - *Ensure that certification examinations are continually reviewed to incorporate new technologies and remove obsolete information."*

The IAAI Certification Program is accredited by both the Professional Qualifications Board (The Pro Board) and the Forensic Specialties Accreditation Board (FSAB). None of the NAFI programs are accredited, but NAFI is reportedly in the process of applying for FSAB accreditation.

Other professional organizations that affect fire investigation include the National Fire Protection Association (NFPA), International Fire Marshals Association (IFMA), Society of Fire Protection Engineers (SFPE), National Association of State Fire Marshals (NASFM), ASTM International, International Association of Special Investigative Units (IASIU), Association of Certified Fraud Examiners (ACFE), the National Association of Subrogation Professionals (NASP) and the American Academy of Forensic Sciences (AAFS).

The NFPA is a global nonprofit organization established in 1896, which now has over 60,000 members. NFPA's mission is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education. NFPA promulgates NFPA 921 and NFPA 1033 which apply directly to fire investigations. NFPA also has several sections, including the International Fire Marshals Association (IFMA). NFPA publishes the *Fire Protection Handbook,* now in its 20th edition, and jointly publishes the peer-reviewed journal *Fire Technology* with SFPE and Springer.

SFPE also publishes the *Handbook of Fire Protection Engineering*, now in its fifth edition. Founded in 1950, SFPE has over 4,000 members, representing those practicing in the fields of fire protection engineering and fire safety engineering. SFPE's mission is to define, develop, and advance the use of engineering best practices; expand the scientific and technical knowledge base; and educate the global fire safety community, to reduce fire risk. Additionally, SFPE offers courses in numerous areas of engineering that are of interest to fire investigators.

The principal membership of NASFM comprises senior fire officials in the United States and their top deputies. The primary mission of NASFM, established in 1989, is to protect human life, property, and the environment from fire and related hazards. A secondary mission of NASFM is to improve the efficiency and effectiveness of State Fire Marshals' operations. In addition to its principal membership of State Fire Marshals, NASFM has several categories of membership to allow companies, associations, academic and research institutions, and individuals who support NASFM's mission to contribute in meaningful ways. State Fire Marshals' responsibilities may vary from state to state, but Marshals tend to be responsible for fire safety code adoption and enforcement, fire and arson investigation, fire incident data reporting and analysis, public education and advising governors and state legislatures on fire protection.

ASTM International (formerly the American Society for Testing and Materials) promulgates more than 12,000 individual standards covering all aspects of products and services. ASTM publishes an 80-volume *Annual Book of Standards*. Founded in 1898, ASTM International is one of the world's largest international standards development organizations. There are more than 30,000 members of the organization who hail from more than 140 countries. ASTM Committee E30 on Forensic Sciences promulgates standards for evidence handling, reporting, and fire debris analysis, among other forensic science disciplines.

Founded in 1984 by a group of insurance industry fraud investigators, the International Association of Special Investigation Units (IASIU) is a non-profit organization dedicated to:

- promoting a coordinated effort within the industry to combat insurance fraud;
- providing education and training for insurance investigators;
- developing greater awareness of the insurance fraud problem;
- encouraging high professional standards of conduct among insurance investigators; and
- supporting legislation that acts as a deterrent to the crime of insurance fraud.

Established in 1988, the Association of Certified Fraud Examiners (ACFE) is a professional organization of fraud examiners. Its activities include producing fraud information, tools, and training. The ACFE grants the professional designation of Certified Fraud Examiner. There are currently over 85,000 members.

The National Association of Subrogation Professionals (NASP), whose members have a keen interest in fire investigations, was founded in 1998 to meet the needs of the subrogation industry. NASP offers a monthly magazine, an annual national seminar, and numerous local seminars.

The American Academy of Forensic Sciences, founded in 1948, consists of nearly 7000 members practicing in 12 distinct forensic science disciplines. The Criminalistics section of the Academy includes fire investigators and fire debris analysts.

2-6 Standards for Fire Investigators

Quality in fire investigation, and indeed in all of the forensic science disciplines, is comprised of three elements: certification for individuals, accreditation for organizations, and standardization of methods. Figure 2-1 shows these elements as the sides of the Quality Triangle in Forensic Science.

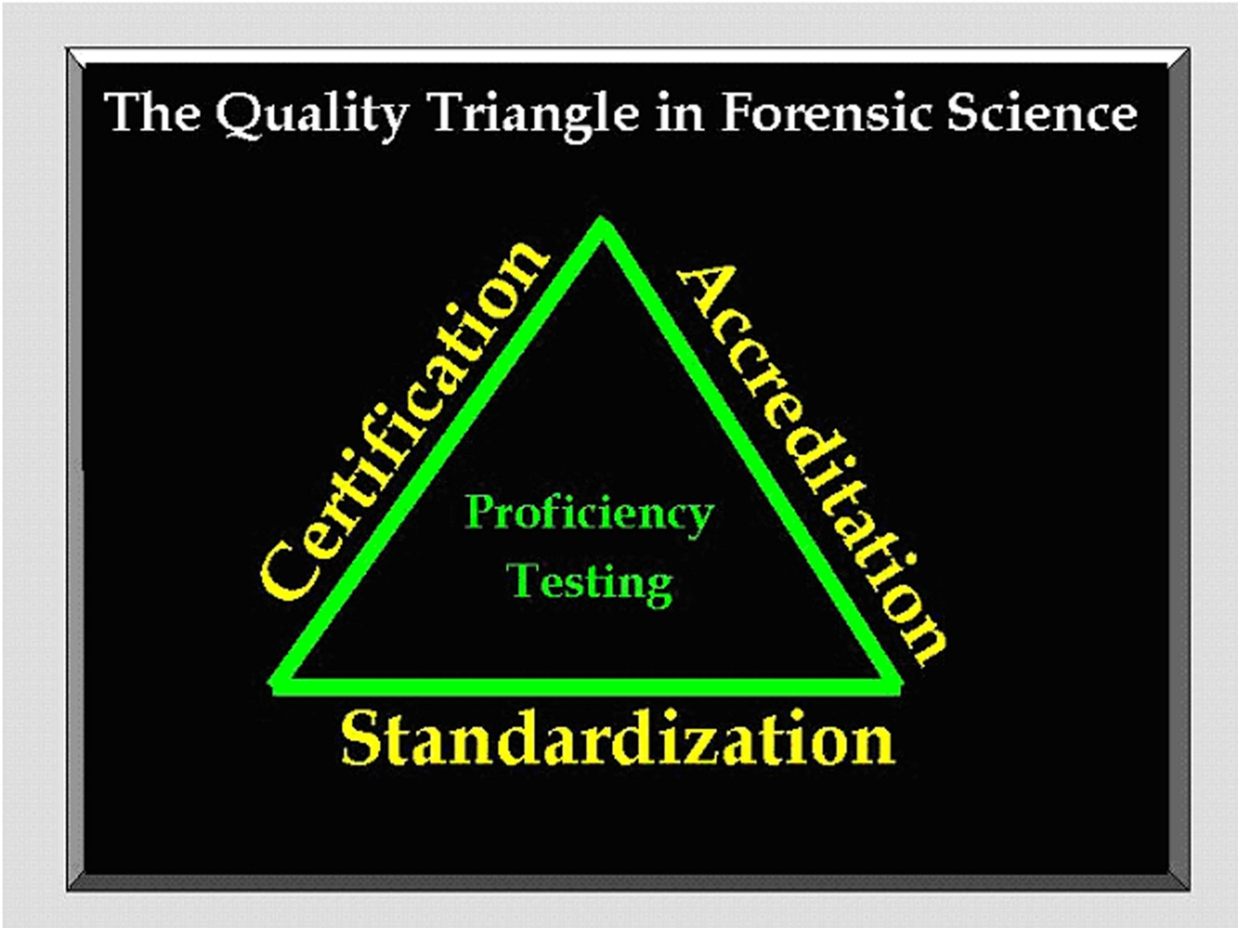

Figure 2-1. The Quality Triangle in Forensic Science. The Quality Triangle is credited to Lawrence Pressley, former Quality Assurance Director at the FBI Laboratory. [Lentini 2018]

There are two overarching consensus documents in fire investigation. NFPA 1033, *Standard for Professional Qualifications for Fire Investigator*, and NFPA 921, *Guide for Fire and Explosion Investigations*. These documents meet the requirements for voluntary consensus documents. Both documents are regularly used in court to challenge the qualifications, methodology, and analysis of the fire investigator. These two documents incorporate other standards by reference, specifically ASTM standards promulgated by Committee E30 on Forensic Sciences dealing with the collection, preservation, and handling of evidence and data, as well as reporting of opinions. Both NFPA 921 and NFPA 1033 are listed on the OSAC Registry. The Fire and Explosion Investigation Subcommittee has submitted recommendations for improving both of these documents to NFPA.

NFPA 1033 [2022] outlines the minimum education, knowledge, and skills necessary to be a fire investigator. This standard applies to both public and private investigators. NFPA 1033 was first published in 1987 and is in its sixth edition. It is revised on a 5-year schedule.

NFPA 921 [2021] outlines the methods, practices, and procedures for properly conducting fire investigations. NFPA 921 was first published in 1992 and is now in its tenth edition. Courts have relied on NFPA 921 as an authoritative source of information about how fire investigations should be performed.[9]

---

[9] *See* Russell v. Whirlpool Corp., 702 F.3d 450, 455 (8th Cir. 2012) (stating that although NFPA standards are not controlling, if the investigators purport to use NFPA 921, they need to "reliably apply" NFPA instructions); Bryte ex rel. Bryte v. Am. Household, Inc., 429 F.3d 469, 478 (4th Cir. 2005) (upholding the district court's exclusion of fire investigation causation testimony where a fire investigator failed "to exclude '[a]ll other reasonable origins and causes'" as mandated by NFPA 921 (alteration in original) (quoting NAT'L FIRE PROT. ASS'N, NFPA 921: GUIDE FOR FIRE AND EXPLOSION INVESTIGATIONS ¶ 2-3.6 (1998 ed. 1998))); Fireman's Fund Ins. Co. v. Canon U.S.A., Inc., 394 F.3d 1054, 1059 (8th Cir. 2005) (holding that the district court did not abuse its discretion in concluding that the fire investigators failed to apply an NFPA 921 evidentiary standard reliably to the facts of the case); Werth v. Hill-Rom, Inc., 856 F. Supp. 2d 1051, 1060 (D. Minn. 2012) (excluding expert-fire-investigator testimony due to the expert's failure to rely on NFPA 921 and, in so doing, stating that "[s]imply put, the experts' failure to disclose their reliance on NFPA 921—in their initial Report, their Supplemental Report, their depositions, or at any other point in discovery—would alone justify excluding their opinion"); Travelers Indem. Co. v. Indus. Paper & Packaging Corp., No. 3:02–CV–491, 2006 WL 1788967, at *4–5 (E.D. Tenn. June 27, 2006) (denying, in part, motion in limine to exclude fire-expert testimony where expert methodology was "consistent with NFPA 921"); Workman v. AB Electrolux Corp., No. 03-4195-JAR, 2005 U.S. Dist. LEXIS 16306, at *31 (D. Kan. Aug. 8, 2005) (allowing admission, in part, of evidence because the investigator's methodology comported with NFPA 921 standards); Tunnell v. Ford Motor Co., 330 F. Supp. 2d 707, 725 (W.D. Va. 2004) (concluding that the expert's testimony "was based on his investigation of the cause of the fire, an investigation which was conducted in accordance with the professional standards and scientific methodology . . . set forth in NFPA 921"); TNT Rd. Co. v. Sterling Truck Corp., No. 03- 37-B-K, 2004 U.S. Dist. LEXIS 13463, at *9, *17–18 (D. Me. July 19, 2004) (allowing admission of evidence that "substantially complied with the NFPA standard"); Ind. Ins. v. Gen. Elec. Co., 326 F. Supp. 2d 844, 851–53 (N.D. Ohio 2004) (finding that reliance on a "suspect investigation . . . impugns the reliability of [the expert's] analysis"); Royal Ins. Co. of Am. v. Joseph Daniel Constr., Inc., 208 F. Supp. 2d

NFPA 921 has been adopted as the standard of care in a number of cases.[10]

In 2004, the American Bar Association House of Delegates called for all forensic science practitioners to be certified, for agencies that employ those practitioners to become accredited, and for the certified practitioners to follow standard methods. The 2009 NAS Report called for the same things, although NAS additionally stated that all of these requirements should be mandatory. The National Commission on Forensic Science also supported universal certification of forensic science practitioners [NCFS 2016] Mandatory certification and best practices should be encouraged.

Although certification is available in fire and explosion investigation, there is almost no accreditation of fire investigation units. (As used in this text, certification applies to individuals, and accreditation applies to organizations.) As of 2019, there were three private sector agencies and one public sector agency accredited by the American Association for Laboratory Accreditation (A2LA) to conduct fire scene investigations. ATF National Response Team is accredited by ANSI National Accreditation Board (ANAB). The OSAC Fire and Explosion Investigation Subcommittee is looking forward to promulgating standards for the accreditation of fire investigation agencies, but this work is just beginning. An NFPA

423, 426–27 (S.D.N.Y. 2002) ("A comparison of [the expert's] methodology and the six steps of the NFPA 921 methodology reveals that his conclusions were based on these recognized standards and not merely his subjective belief."); Snodgrass v. Ford Motor Co., No. 96-1814(JBS), 2002 U.S. Dist. LEXIS 13421, at *48, *56–57 (D.N.J. Mar. 28, 2002) (allowing expert to testify to his opinions on fire causation as long as said opinions did not rely on unreliable statistics); Chester Valley Coach Works v. Fisher-Price, Inc., No. 99 CV 4197, 2001 WL 1160012, at *8–13 (E.D. Pa. Aug. 29, 2001) (noting that an expert's deviations from NFPA 921 methodologies gave the court "serious doubts as to the . . . conclusions that [the expert] reached"); Travelers Prop. & Cas. Corp. v. Gen. Elec. Co., 150 F. Supp. 2d 360, 365–66 (D. Conn. 2001) (remarking that an expert's methods were consistent with "the principles of NFPA 921"). *But see* Schlesinger v. United States, 898 F.Supp.2d 489, 504 (E.D.N.Y. 2012) ("courts frequently exclude expert testimony for failure to comply with NFPA 921 in circumstances where the expert explicitly relies on NFPA 921 in reaching his or her conclusion," but "the Court is aware of no court in this circuit that has refused to admit expert testimony in an arson case because his or her opinion was based on a methodology other than that prescribed in NFPA 921 … .").

[10] *See id.*

Committee has been created to develop the standard, and a draft standard has been proposed by the Fire and Explosion Investigation Subcommittee of OSAC. The standard, NFPA 1321, is in the early developmental stages prior to beginning full public review and initial revision cycle. Such a standard will provide the basis for completion of the Quality Triangle in Forensic Science for fire and explosion investigations.

2-7 Conclusions

Today's fire investigation profession offers numerous avenues for professional development. Fire investigators and the agencies that employ them are urged to avail themselves of these opportunities. Staying abreast of current research is required if an investigator wishes to become and remain credible. Investigators are encouraged to join professional organizations, attend training, read journals, and most importantly, become certified.

The methodology of fire investigation has changed dramatically over the last three decades, as the industry has moved from art to science. The profession has chosen to use the open committee process at NFPA so that everyone has an opportunity to participate. The content of the NFPA 921 and NFPA 1033 documents are the result of thousands of public comments and hundreds of face-to-face meetings. All investigators and agencies are encouraged to become involved in the process.

REFERENCES

Lentini, J., *Scientific Protocols for Fire Investigation*, 3rd Edition, CRC Press, 2018.

Madrzykowski, D., The Future of Fire Investigation, Fire Chief, October 2000.
http://www.interfire.org/pdf/Madrzykowski.pdf

Mealy, Wolfe, & Gottuk, (2013), Forensic Analysis of Ignitable Liquid Fuel Fires in Buildings, NCJRS, Document # 241441.
https://www.ncjrs.gov/pdffiles1/nij/grants/241441.pdf

National Commission on Forensic Science (2017), Work Products of the NCFS, https://www.justice.gov/archives/ncfs/work-products-adopted-commission

Putorti A. (1997), Full Scale Room Burn Pattern Study. NIJ Report 601-97, National Institute of Justice, Washington, D.C., December 1997. https://www.nist.gov/publications/full-scale-room-burn-pattern-study-nij-report-601-97

Shanley, J. H. Jr.; et al.;(1997) "Federal Emergency Management USFA Fire Burn Pattern Tests." Report of the United States Fire Administration Program for the Study of Fire Patterns, FA 178; p. 221. https://app.box.com/s/z2ws7harx94levwxnf7cy3e2x0akz3fg

3. THE ADMISSION OF FIRE AND EXPLOSION INVESTIGATION EVIDENCE IN LITIGATION

3-1 Science and the Law

As Justice Blackmun observed in the *Daubert* decision, "There are important differences between the quest for truth in the courtroom and the quest for truth in the laboratory. Scientific conclusions are subject to perpetual revision. Law, on the other hand, must resolve disputes finally and quickly."

According to the 2009 NAS report,

> "The adversarial process relating to the admission and exclusion of scientific evidence is not suited to the task of finding 'scientific truth.' The judicial system is encumbered by, among other things,
>
> - judges and lawyers who generally lack the scientific expertise necessary to comprehend and evaluate forensic evidence in an informed manner,
> - trial judges (sitting alone) who must decide evidentiary issues without the benefit of judicial colleagues and often with little time for extensive research and reflection, and
> - the highly deferential nature of the appellate review of afforded trial courts' *Daubert rulings*.
>
> Given these realities, there is a tremendous need for the forensic science community to improve. Judicial review, by itself, will not cure the infirmities of the forensic science community."

It is, therefore, incumbent upon the practitioners of forensic science, including fire investigators, to improve their reliability through leadership, professionalism and valid research, to meet the needs of the criminal and civil justice systems.

The trial court judge has always controlled the admission of evidence, including expert evidence, at trial, but empirical research has shown that the admission decision varies by factors such as which party is proposing the testimony and the type of case. Considering the status of the case and the state of the law, prosecutors, defense attorneys, and civil litigators must therefore decide, often with input from their experts, which evidence to attempt to present. In criminal cases, judges may be wish to avoid appeals by having a permissive approach to admissibility and allowing the jury to decide which side has the best experts.[11]. In criminal cases, expert testimony is commonly allowed.[12]. As a practical matter, appellate court decisions often involve evaluation of testimony from civil cases. [NAS 2009] Yet because of the deferential "abuse of discretion" standard applied to admissibility decisions, these appellate cases may not necessarily reflect the overall approach taken at the trial court level, where decisions are commonly unwritten or unpublished. The appellate record for challenges to fire investigations will be discussed below.

Before the 1993 *Daubert* decision, the prevailing authority on admissibility of scientific evidence was the *Frye* case, a 1923 case from the Court of Appeals for the District of Columbia.[13] In this murder case, the defense attempted to introduce a "systolic blood pressure deception test," a predecessor of the polygraph with the same function, which the expert would testify that the defendant passed. After the trial court did not allow the testimony, the defendant appealed. On appeal, the court held that to be admissible, a scientific technique had to be "generally accepted by the relevant scientific community." Even after the Supreme Court decision in

---

[11] Risinger, D. M., [2000] "Navigating Expert Reliability: Are Criminal Standards of Certainty Being Left on the Dock?" 64 ALB. L. REV. 99, 101, 104.

[12] See id.

[13] Frye v. United States, 293 F. 1013, 1013 (D.C. Cir. 1923).

Daubert in 1993 changed the standard of review in federal court, a number of states continue to apply *Frye* for admissibility determinations in their state courts.

In its 1993 *Daubert* ruling, the Supreme Court provided significant guidance to judges on how to consider proposed testimony in the form of non-exclusive list of factors a trial court judge could consider, including the *Frye* general acceptance factor. Even though many "friends of the court" warned that moving away from general acceptance to a broader standard for admission would result in courts being bombarded with "junk science," the *Daubert* decision seems to have encouraged more reliability challenges or at least has resulted in judges paying closer attention to their responsibility as gatekeepers. [Risinger 2000] As a result of increased scrutiny overall, there have been far more experts challenged since *Daubert* than were challenged beforehand.

In 2000, the Federal Rules of Evidence were amended to reflect the Supreme Court's language from the *Daubert* trilogy.[14] Rule 702, which formerly required "scientific, technical, or specialized knowledge" that "will assist the trier or fact" for testimony to be qualified, now requires that:

> **(a)** the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
> **(b)** the testimony is based on sufficient facts or data;
> **(c)** the testimony is the product of reliable principles and methods; and
> **(d)** the expert has reliably applied the principles and methods to the facts of the case.

As of 2019, a majority of states have adopted the *Daubert* standard for use in their state courts, while a smaller number of states still operate under

[14] The "*Daubert* trilogy" consists of the original *Daubert* decision, 509 U.S. 579 [1993], the *GE v. Joiner* decision, 522 U.S. 136 [1997] and the *Kumho v. Carmichael* decision, 526 U.S. 137 [1999].

the *Frye* standard. At least three states (NV, ND, VA) have a unique state-specific standard [Morgenstern, 2020] In all jurisdictions, the gatekeeping standard is primarily a standard intended to ensure the reliability of expert testimony.

3-2 Reports and Testimony

Documentation is an essential part of the scientific method. According to NFPA 921, "Thorough and accurate documentation of the investigation is critical because it is from this compilation of factual data that investigative opinions and conclusions can be supported and verified" [NFPA 921-2021 at 16.1.2]. Reports serve two functions. The first is to communicate the investigator's methodology and findings, while the second is to aid the investigator in recreating his findings and thought processes sometime in the future. Most fire investigations end with the preparation of an expert report.

The length, content, and level of detail required in a report vary widely depending on the investigator's jurisdiction and assignment. In the Federal system, the report format is dictated by Federal Rule of Civil Procedure 26 for civil cases and Federal Rule of Criminal Procedure 16 for criminal cases. Some states will have similar rules, but the level of disclosure var by jurisdiction. Generally, the rules require greater levels of disclosure in reports created for use in civil cases. In some jurisdictions, however, the law will not require any expert report. Whether a report is needed or not, discovery of an expert's opinion may be required by rules of disclosure, and if so, the disclosure would require a document filed by sponsoring counsel that states the expert's opinions. In jurisdictions where sponsoring counsel summarizes the expert's opinion, it is important for the expert to coordinate closely with counsel to make sure the disclosure is accurate.

In some cases, discovery may also include expert depositions, involving sworn testimony by the expert who is questioned by adverse counsel without a judge present. Other jurisdictions do not allow expert depositions, so the attorneys learn what the expert will say during the trial. In still other jurisdictions the only opinions an expert is allowed to express at trial are what is in the "four corners" of the expert's report.

As for criminal cases, a small number of states (FL, IA, IN, NH, and VT), allow depositions in criminal cases, and every person on the witness list of both sides may be subject to being deposed. In federal criminal cases and in most states, depositions are generally not allowed. It is thus important for an investigator to be familiar with the rules governing discovery.

According to Federal Rule of Civil Procedure 26, an expert's report must contain:

> *(1) a complete statement of all opinions the witness will express and the basis and reasons for them;*
> *(2) the facts or data considered by the witness in forming them;*
> *(3) any exhibits that will be used to summarize or support them;*
> *(4) the witness's qualifications, including a list of all publications authored in the previous 10 years;*
> *(5) a list of all other cases in which, during the previous 4 years, the witness testified as an expert at trial or by deposition; and*
> *(6) a statement of the compensation to be paid for the study and testimony in the case.*

In criminal cases, the report requirements are only slightly less detailed. Federal Rule of Criminal Procedure 16 states,

> *" (G)* Expert Witnesses. *At the defendant's request, the government must give the defendant a written summary of any testimony that the government intends to use under Rules 702, 703, or 705 of the Federal Rules of Evidence during its case-in-chief at trial. If the government requests discovery under subdivision (b)(1)(C)(ii) and the defendant complies, the government must, at the defendant's request, give to the defendant a written summary of testimony that the government intends to use under Rules 702, 703, or 705 of the Federal Rules of Evidence as evidence at trial on the issue of the defendant's mental condition. The summary provided under this subparagraph must describe the witness's opinions, the bases and reasons for those opinions, and the witness's qualifications."*

ASTM E620 (which is referenced by both NFPA 921 and NFPA 1033) the *Standard Practice for Reporting the Opinions of Technical Experts*, applies to fire investigators. It provides guidance on logic and reasoning based methodology for the investigator for creating, critiquing, evaluating, supporting, and eliminating hypotheses. To meet the criteria for transparency, the source, scientific and technical basis, and the relationship of each hypothesis and criterion to known incident data is specified in addition to addressing the relative scientific or technical merits of alternate hypotheses supported and eliminated by the available data. Opinions or conclusions must account for all known relevant facts related to the incident and be consistent with accepted scientific and logical principles. [NFPA 921-17 at A.4.3.2]

Report preparation is one of the job performance requirements (JPRs) found in NFPA 1033. The NFPA 1033 requirement is similar to that expressed in ASTM E620. NFPA 1033 Section 4.7.1 states, "Prepare a written report, given investigative findings, documentation, and a specific audience, so that the report accurately reflects the investigative findings, is concise, expresses the investigator's opinion, contains facts and data that the investigator relies on in rendering an opinion, contains the reasoning of the investigator by which each opinion was reached, and meets the needs or requirements of the intended audience(s)."

3-3 Level of Certainty

NFPA 921 in the chapter on Basic Methodology addresses the level of certainty, and it states, "The level of certainty describes how strongly someone holds an opinion (conclusion). Someone may hold any opinion to a higher or lower level of certainty. That level is determined by assessing the investigator's confidence in the data, in the analysis of that data and testing of hypotheses formed. That level of certainty may determine the practical application of the opinion, especially in legal proceedings."

NFPA 921 further states that many courts have set a threshold of certainty for the investigator to be able to render opinions in court such as "proven to an acceptable level of certainty," "a reasonable degree of scientific and engineering certainty," or "a reasonable degree of certainty within my profession."

The National Commission on Forensic Science [NCFS 2016], on the other hand, has addressed the level of certainty that some lawyers and judges mistakenly believe is required for testimony. That is "a reasonable degree of scientific (or medical, or engineering, or discipline) certainty." In fact, "scientific certainty" does not exist. It is a term of art coined by lawyers and is now falling into disrepute.

On March 22, 2016, the NCFS voted to recommend that the term "reasonable certainty," whether couched as "scientific certainty" or "[discipline] certainty", **should not be used**. It recommended that the Attorney General direct all attorneys appearing on behalf of the DOJ (a) to forgo the use of these phrases unless directly required by judicial authority as a condition of admissibility of the witness's opinion and (b) to assert the legal position that such terminology is not required and is indeed misleading. The second recommendation to the Attorney General states that the AG should direct all forensic science service providers and forensic science medical providers employed by the DOJ not to use such language in reports or to couch their testimony in such terms unless directed to do so by the judge. A final recommendation adopted by the NCFS is that the Attorney General should, in collaboration with NIST, urge the OSAC to develop appropriate language that may be used by experts when reporting or testifying about results or findings based on observations of evidence and the data derived from the evidence. [NCFS 2016]

The DOJ is continuing the process of developing guidance documents governing the testimony and reports of its forensic experts. These documents, which are being developed for each forensic science discipline, are known as "Uniform Language for Testimony and Reports," or ULTR documents. The ULTRs are designed to provide guidance on the submission of scientific statements by the Department's forensic examiners when drafting reports and testifying.

According to one legal scholar

> *"The reasonable-degree-of-scientific-certainty language almost certainly was drafted by the lawyers. Scientists have no use for this phrase (outside the courtroom). Indeed, "a reasonable degree*

> *of scientific certainty" is not a defined concept in scientific disciplines or even in law. … It is legal mumbo-jumbo derived from archaic cases in which lawyers discovered that if a medical doctor did not utter the incantation "to a reasonable degree of medical certainty," his testimony might be excluded because doctors were not supposed to talk about mere probabilities." [Kaye 2010]*

The problem with testifying to a "reasonable degree of scientific certainty" is that a jury might equate it with certainty at the level of beyond a "reasonable" doubt.

The OSAC Subcommittee on Fire and Explosion Investigations urges fire investigators to follow the NCFS Recommendations and avoid the use of the term "reasonable degree of scientific [or discipline] certainty" unless the Court insists. The Subcommittee may address further limitations on testimony in the future.

3-4 The Impact of *Daubert* and NFPA 921 on Fire Investigation Testimony

The first edition of NFPA 921 was published just a year before the *Daubert* decision was handed down. The first appellate decision on the applicability of *Daubert* to fire investigation was handed down by the 11th Circuit in 1998 in the case of *Michigan Millers Mutual Insurance Corp. v. Jeanelle Benfield*. This was an arson case from Sarasota Florida, wherein Michigan Millers filed a declaratory action in federal court seeking to void the contract of insurance because of arson and misrepresentation. Miller's expert had his testimony excluded because according to the Court,

> *"At trial, Millers' fire causation expert tried to explain how he came to the conclusion that the fire in the Benfield home was intentionally set. Buckley stated at trial that he came to his opinion that the fire was intentionally set by eliminating all accidental causes, and by determining that, given that the fire began on the dining room table, there were no other possible sources of ignition of the fire. Essentially,*

> *the testimony of Buckley reveals that he came to his opinion that the fire was incendiary largely because he was unable to identify the source of the ignition of the fire. In determining that the fire was incendiary, Buckley performed no tests and took no samples. At trial, Buckley was unable to describe the chandelier that hung over the table and unable to explain the methodology by which he eliminated the chandelier as a possible ignition source for the fire. After telling the jury on direct that he believed someone poured lamp oil from the lamp oil bottle over the clothes and set the clothes ablaze, on cross-examination Buckley admitted that he did not know even if the lamp oil bottle had contained lamp oil before the fire and that there was no scientific basis for such an opinion. With such testimony as a backdrop, the district court granted the motion by Mrs. Benfield to strike the testimony of Buckley, finding that while Buckley held the opinion that the fire was intentionally set, he was unable to rationally explain how he came to that conclusion."*

The Appeals Court found that Buckley's testimony was, in fact, scientific, and therefore subject to scrutiny under *Daubert*. The Court did not credit the *amicus* brief filed on behalf of the International Association of Arson Investigators (IAAI), which argued that because fire investigation was "less scientific" than the kind of testimony envisioned under *Daubert*, "An application of a strict *Daubert* analysis to a cause and origin investigation is improper."

The 11th Circuit's ruling had a curious effect on fire investigation. Because the Court held that a fire fighter's testimony was admissible because he based his findings on "experience" instead of "science," certain litigators began encouraging fire investigators to avoid the use of the word "science" in their reports and testimony. This ill-conceived advice became moot in 1999 when the Supreme Court, ruling in the *Kumho* case (which also originated in the 11th Circuit) held that *Daubert* inquiries on reliability applied to **all** expert testimony, whether it was based on scientific, technical or other specialized knowledge. In its unanimous decision, the Supreme Court relieved trial court judges of deciding whether expert testimony was *scientific*. The trial judge's gatekeeping task was to determine whether the proposed testimony was *reliable*.

After the *Kumho* decision, the IAAI and the fire investigation profession in general, realized that fire investigations should be conducted according to the precepts of science, but not before fighting one last battle. Although the Supreme Court had already made all fire investigator testimony subject to a reliability inquiry, more than a hundred comments were submitted to the NFPA for the 2001 edition of NFPA 921, protesting the Technical Committee's decision to continue to recommend the use of the scientific method. Many arguments were made in support of a "systematic approach" instead of the scientific method. These arguments revealed a lack of understanding of what constitutes a scientific investigation.

One change was made in the description of the scientific method, which the NFPA Technical Committee hoped would eliminate the contention that to "scientifically" test a hypothesis, one needed to rebuild the building and then burn it down again. In the paragraph on hypothesis testing, the following sentence was added: "This testing of the hypothesis may be either cognitive or experimental." This statement explained the proposition that as long as deductive reasoning was used to test the hypothesis, a physical experiment was not a necessity. Some fire investigators took this as a license to merely think about the fire scene and rely on their experience, as they had in the past, but the subsequent edition of NFPA 921, published in 2004, provided more details about the use of inductive and deductive reasoning.

It was in 2000 that the leadership of the IAAI endorsed the adoption of the next (2001) edition of NFPA 921. IAAI President Gerard Naylis said at the time that it was time for the IAAI to start looking out the windshield and stop looking at the rearview mirror. (It should be noted that the leadership of NAFI had endorsed NFPA 921 as the "standard of care" for fire investigation since the first edition.)

Also in 2000, the U. S. Department of Justice, NIJ issued a research report entitled ***Fire and Arson Scene Evidence: A Guide for Public Safety Personnel*** [NIJ 2000] , which contains the following statements about NFPA 921:

> *"In 1992, the National Fire Protection Association (NFPA) issued NFPA 921: Guide for Fire and Explosion Investigations, a consensus document reflecting the knowledge and experience of fire, engineering, legal, and investigative experts across the United States. This document is continuously reviewed, public proposals and comments are solicited, and a revised edition is produced every 3 to 5 years. It has become a benchmark for the training and expertise of everyone who purports to be an expert in the origin and cause determination of fires.*
>
> *The investigator should recognize the limitations of his or her own expertise and determine what personnel may be required to process the scene according to NFPA 921 and other recognized national guidelines. If neither the origin nor the cause is immediately obvious, or if there is clear evidence of an incendiary cause, the investigator should conduct a scene examination in accordance with NFPA 921 and other recognized national guidelines or seek someone with the expertise required."*

Over the next few years, trial courts began to recognize the authority of NFPA 921, excluding testimony if an investigator's methodology deviated significantly from its guidance, and admitting it if the 921 methodology was followed [Lentini 2007]. Due to the deferential "abuse of discretion" standard for review of a trial court's decisions on admissibility, most rulings on admissibility are not published, and sometimes not even written. A subscription decision reporting service called DaubertTracker (www.DaubertTracker.com) lists over 1,800 court decisions on *Daubert* challenges to fire investigators, and most of these decisions reference NFPA 921. Some frequently cited cases are discussed below.

Weisgram v. Marley Co. 528 U.S. 440 [2000]

This case arose out of a December 30, 1993 Fire in Fargo, ND that was fatal to Bonnie Weisgram, who died from smoke inhalation. Three experts attributed the cause of the fire to a 15-year-old electric baseboard heater manufactured by Marley. The expert testimony was admitted at trial, and the jury awarded $500,000 to Bonnie's son Chad and $100,000 to State Farm insurance for their subrogated loss. Marley appealed the case to the Eighth Circuit, arguing that the experts' testimony should have been excluded.

On February 23, 1999, the Eighth Circuit held that the District Court judge had abused his discretion by admitting the expert testimony and that he should have granted Marley a judgment as a matter of law. The Court examined both the qualifications and the methodology of the experts and applied the Supreme Court's decision in *GE v. Joiner.*

The Eighth Circuit's decision was appealed to the Supreme Court, where it was upheld. The fire took place shortly after the *Daubert* decision was handed down, and the appeal took place after the *Joiner* decision set out the "abuse of discretion" standard for review. At the time of the Eighth Circuit's decision, the *Kumho* case was pending before the Supreme Court.

The experts were a Fire Chief, who the Eighth Circuit said had properly been allowed to testify about the origin of the fire but was improperly allowed to speculate as to the cause. A second expert, an electrical expert was excluded as merely speculating. His determination was based on "everything else being ruled out" by the Fire Chief. He had not visited the fire scene. He opined that after operating for 15 years without incident, both the thermostat and the high limit control suddenly and simultaneously did not function to shut the heater off. He was unable to get an exemplary heater from the same apartment building to similarly malfunction and testified that he had no idea what caused the thermostat to fail, and agreed that there were no design defects. The Eighth Circuit stated that the District Court abused its discretion by permitting him to testify as an expert witness regarding matters about which he could only speculate.

The third expert was a metallurgist with no experience in heater design or contact design. He opined that because the contacts were serrated, they were badly designed, even though he did not know the heater wattage or what temperature it might attain.

In a finding that shows the inherent problems in allowing non-scientists to rule on scientific evidence, the Court found that in order to be defective, this heater would have had to sustain *two simultaneous failures*. It is clear that either the high limit thermostat *or* the operating thermostat could have failed years before the fire, and there was no requirement that the failures be simultaneous.

Truck Insurance Exchange v. Magnetek 360 F. 3d 1206 [2004]

This case arose out of a November 9, 1998 fire at Sammy's restaurant in Lakewood, Colorado. Upon their arrival, the fire department found only smoke, no fire, until the fire caused the kitchen floor to collapse, indicating a fire in the basement. There was a fluorescent light in the basement and according to the experts, no other potential ignition source. Thus, the light must have been the cause.

The ballast in the light, however, contained a thermal cut off (TCO) which still functioned after the fire and operated at 232 F. A similar ballast, when shorted, reached a stable temperature of 300 F.

There is a never-proven hypothesis that, upon continued exposure to a heat source below its ignition temperature, the ignition temperature of wood can be lowered to a point where a heat source of only 200 F might ignite it. This was the plaintiff's case against Magnetek.

The trial court agreed with Magnetek when it moved for summary judgment and the exclusion of the plaintiff's electrical engineer. Truck appealed to the 10th Circuit but lost. In this case, the 10th Circuit ruled that the theory of pyrophoric carbon had never been demonstrated in the laboratory, so it was not admissible as evidence. Unfortunately, the court adopted some incorrect terminology and ended up stating that pyrolysis, a necessary phenomenon that precedes the combustion of wood, did not occur.

Acknowledging the terminology problem, the Court held, "We note that there appears to be some confusion among the parties, the District Court, and even the scientific community as to the proper terminology for the theory of long-term low-temperature and the charring it involves. This court is not in a position to decide such questions for the scientific community, but for this opinion, we will refer to this *process* as 'pyrolysis.' To the extent that we use the term 'pyrophoric carbon,' we are talking about the *substance* charred wood." They further held that the District Court did not abuse its discretion when it ruled that under the *Daubert* trilogy, pyrolysis was not yet a scientifically reliable theory upon which to base an expert opinion about the cause of the Sammy's fire. This case again illustrates that courts are not in a position to decide scientific questions. In its conclusion, the 10th Circuit noted that the theory of long-term, low-temperature ignition of wood was interesting, and one which may eventually be sufficiently tested and researched to serve as the basis for an expert opinion under Rule 702. However, the Court was clear in its opinion that the theory has yet to reach that point and that, as a consequence, expert opinions based on the theory should be carefully scrutinized.

Bryte v. American Household, Inc. Fourth Circuit No. 04-1051

Lova Bryte, a paralyzed stroke victim from West Virginia, died in an October 3, 2000 fire while sitting in her chair, and a state fire marshal opined that the ignition source was an electric blanket. The trial court excluded the fire marshal's testimony because he had failed to examine, consider and eliminate other potential causes of the fire in the area of the blanket, which included other electrical devices and a candle. The Fourth Circuit Court of Appeals held that the District Court did not abuse its discretion in excluding the testimony, describing the record as "so speculative that a jury has to guess to determine whether there is liability of either the warranty or negligence for the jury to speculate on."

The court found that the fire marshal's opinion was reached in contravention of NFPA 921's guidance that "all other reasonable origins and causes be excluded."

Carr v. Georgia [1997] Ga. LEXIS 104.

This case arose out of an April 7, 1993 fire, in which Mr. Carr was convicted of setting a fire in order to kill his wife. The case had many interesting aspects, but Mr. Carr's conviction was overturned based on the admission of evidence of 12 unconfirmed accelerant detection canine (ADC) alerts.[15]

It was the *Carr* case that prompted the introduction of a tentative interim amendment (TIA) to NFPA 921 in 1996.[16] The tentative interim amendment was adopted in 1997, and the Georgia Supreme Court took note of the change to NFPA 921 in its deliberations. In its decision, the Georgia Supreme Court wrote,

> *"While the use of trained dogs can be a valuable part of investigative procedures and can provide important elements of probable cause to search … , dog alerts to accelerants have not been shown, either at the trial of this case nor in any Georgia appellate decision, to have the scientific reliability necessary to permit their use as substantive evidence of the presence of accelerants. The trial court's ruling to the contrary was error. The State argues that the admission of the evidence, if error, was harmless in light of other evidence of the presence of an accelerant. However, there was no other direct evidence of the presence of an accelerant, and thus, no direct evidence of arson."*

Wisconsin v. Joseph Awe, Marquette County Case No. 07 CF 54

This is another case where changes to NFPA 921 persuaded the court to overturn a conviction. A fire occurred on September 11, 2006, at Mr. Awe's place of business, JJ's Pub. Investigators for the state and his insurance company, working together, concluded that the fire was intentionally set

---

[15] The term "Accelerant Detection Canine" has been updated to the more neutral "Ignitable Liquid Detection Canine," abbreviated as IGL Canine.

[16] A TIA is an emergency change to an NFPA document that can only occur when waiting until the next scheduled edition would cause irreparable harm. In this case, there was a body of law forming around unconfirmed canine alerts, and the Technical Committee on Fire Investigations persuaded the NFPA Standards Council that waiting until 1998 would only encourage more admissions of unreliable evidence.

based admittedly on the application of "negative corpus" methodology. [17] They could find no potential accidental sources of ignition at their hypothetical origin.

Unfortunately, the origin determined by these investigators was incorrect. Across the room, there was a pattern very similar to the fire pattern at the alleged origin, but this pattern had an ignition source associated with it. There was an electric service distribution panel with its cover removed, and that exhibited clear signs of malfunction. That evidence eluded both the insurance company's and the defendant's electrical engineers.

Between the time Mr. Awe was convicted in 2007 and the time his appeal was heard by the trial court, NFPA 921 had been changed to disparage the use of "negative corpus" methodology. The judge found that this change in NFPA 921 constituted "new evidence," and ordered a new trial as a result. In his ruling, the judge wrote, "This is not the fault of the State's arson investigators, who were trained in the flawed methodology. It is the result of the maturation of the arson investigation field, a gradual process of taking a second look at the negative corpus thinking." Mr. Awe was freed shortly after that when the state agreed that without resorting to negative corpus thinking, it could not prove that the fire was intentionally set.

After his release, Mr. Awe went on to sue both his insurance carrier and the electrical engineer that the insurance carrier had retained and was successful in both actions.

Other Daubert Challenges

There have been several review articles published on the effects of *Daubert* and its progeny (the *Joiner* and *Kumho* cases) on fire investigation testimony. Sufficient cases have been decided that the case law may be said

---

[17] NFPA 921-21 at 19.6.5 describes negative corpus methodology as follows: "Identifying the ignition source for a fire by believing to have eliminated all ignition sources found, known, or suspected to have been present in the area of origin, and for which no supporting evidence exists, is referred to by some investigators as *negative corpus*. "

to be settled (no longer subject to change), and so most of these articles are a decade or more old. In 2006, Rauschwerger and colleagues published "The Big *Daubert* Hurdles in Fire & Explosion Litigation," which lists several instructive cases. [Rauschwager et al. 2006]

3-5 The Impact of NFPA 1033 on Fire Investigation Testimony

NFPA 921 has seen a long history of use by attorneys attempting to challenge the methodology of fire investigators. Fire investigators who wish to avoid being challenged with NFPA 921 have traditionally taken coverage in the fact that NFPA 921 is "only a guide." This is not a very effective means of avoiding cross-examination, because the question "Why did you not follow the standard?" simply becomes "Why did you not follow the guide?"

NFPA 1033 has not been used nearly as often in litigation as NFPA 921, and there is no record of an investigator being excluded for failing to adhere to it, but it has received some mention. In *McCoy v. Whirlpool*, a case that describes NFPA 921 as "the gold standard," the defense expert was challenged because he failed to cite NFPA 1033 in his report. The court found that this failure was not sufficient to exclude the expert because it found that the expert was eminently qualified. Plaintiffs argued that NFPA 1033 was so basic, that the expert's failure to mention it showed him to be unqualified, while defendants argued that NFPA 1033 was so basic that it is obvious that the expert would follow it, and there was no need to mention it. The court said that the failure to cite NFPA 1033 was not disqualifying, but it could be used on cross-examination. [*McCoy v. Whirlpool* 2003]

In another case involving Whirlpool, the defendant sought to exclude the plaintiff's expert because he had never designed a refrigerator. The court denied the motion and in addressing the qualifications issue noted that the expert was qualified under NFPA 1033. [*Thompson v. Whirlpool* 2008]

In another case, NFPA 1033 was cited in the expert's resume, leading the court to believe that in addition to following proper methodology, he was "qualified as an expert given his 15 years of experience in numerous training classes, citing, among other things, fire and explosion investigations utilizing NFPA 1033 and 921."[*Young v. Allstate* 2010]

Changes in the 2009 edition of NFPA 1033 have made it a much more useful tool for challenging fire investigators. It is a short document with mandatory requirements, and the addition in 2009 of a list of subjects on which the fire investigator is required to have knowledge beyond the high school level has made challenging fire investigators a straightforward exercise by asking a question such as: "What are the basic units of energy?" "What are the basic units of power?" "What is the difference between energy and power?"

Investigators who are unable to answer this type of question may have a difficult time persuading the court that they are qualified according to NFPA 1033 but failing to answer these questions correctly tends to short-circuit the process. Instead of trying to convince *a judge* that one is qualified despite the lack of mandatory knowledge, the task becomes trying to convince *a sponsoring attorney* that one is qualified. Challenges to experts who are unable to answer basic questions about fire chemistry and fire dynamics need not go as far as court if the sponsoring attorney decides not to use the expert. For this reason, cases, where the expert has demonstrated a lack of knowledge, tend to be settled or dismissed. [Reis, 2015]

The following is an excerpt of a motion challenging a witness who "flunked" a basic NFPA 1033 quiz at his deposition. This motion *in limine* was filed in a subrogation case in which the Plaintiffs alleged the negligent installation of a water heater.

> *"[Witness] is Plaintiff's origin and cause expert and his testimony is the cornerstone of Plaintiff's theory of causation of the fire. However, his testimony establishes that he lacks the basic knowledge to conduct a reliable fire scene investigation and his opinions are unreliable. … [Witness] testified that (1) he did not know the difference between energy and power; (2) he could not identify the basic units of power; (3) he could not define energy release rate; (4) he could not tell how heat release rate was measured; (5) he could not define the term*

> *"watt"; and (6) he did not know the maximum heat flux in the fire. [Witness] could not define the term "fire chemistry." [Witness] could not explain the difference between a vapor and a gas. [Witness] testified that he did not know whether the tankless water heaters in question were fueled by natural gas or propane and he does not know the chemical formula of propane, the volume of oxygen it takes to react with one volume of propane and that he had not taken any classes in thermometry. [Witness] testified that NFPA 1033 applied to his fire scene investigation. [Witness] acknowledged that NFPA 1033 lists 16 topics that fire investigators should have knowledge of beyond the high school level. He could not name any of the 16 topics."*

While NFPA 921 is, in fact, a guide, NFPA 1033, which is a mandatory standard, cites to NFPA 921 as the source of the knowledge an investigator is required to possess, thus making a bridge between the two documents. [Hewitt and McKenna 2014] Challenges to expert qualifications as opposed to methodology are likely to become more common, although because of cases settling, there may not be a substantial body of law as a result.

3-6 Conclusion

NFPA 921 has become so entrenched in the post-*Daubert* world of fire litigation that fire investigators are obliged to at least testify that they followed it or be able to articulate why they deviated from its guidance. Although the first two decades of *Daubert* challenges relied on NFPA 921, more direct "Rule 702" challenges of the investigator's qualifications based on NFPA 1033 are likely to become more common. This should result in a more careful vetting of fire investigators proposing to give expert testimony, and an overall improvement in the quality of evidence presented to courts and juries.

REFERENCES

Hewitt, TD and McKenna WJ, (2014) A Perfect Storm Brewing for Fire Investigators in Court.

http://ssrn.com/abstract=2381519

David H. Kaye, (2010), *The Double Helix And The Law Of Evidence*, Harvard University Press.

Lentini, J. (2007) "The Standard of Care in Fire Investigation." Canadian Association of Fire Investigators. https://drive.google.com/drive/folders/1d_V2v8q8fkWAmsxCD3icf6Qi-LYziR47

McCoy v. Whirlpool Corp., District of Kansas; 2003 U.S. Dist. LEXIS 6901. http://www.leagle.com/decision/20051566379FSupp2d1187_11457/McCOY%20v.%20WHIRLPOOL%20CORP.

Morgenstern, M., (2020) Daubert v. Frye-A State-by-State Comparison. https://www.theexpertinstitute.com/author/morgenstern/

NIJ (2000), Fire and Arson Scene Evidence: A Guide for Public Safety Personnel, Office of Justice Programs https://www.ojp.gov/pdffiles1/nij/181584.pdf

NCFS, Recommendations to the Attorney General Regarding Use of the Term "Reasonable Scientific Certainty" March 3, 2016. https://www.justice.gov/ncfs/file/839726/download

NFPA 921 (2017): *Guide for Fire and Explosion Investigations*, NFPA, Quincy, MA. http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=921

NFPA 921, Fall 2000 Meeting, Report on Comments, NFPA, Quincy, MA, 2000, 437. http://www.nfpa.org/Assets/files/AboutTheCodes/921/ROCF2000-921.pdf

Rauschwager, et al., (2006) "The Big Daubert Hurdles in Fire & Explosion Litigation," *The Subrogator*, NASP.

https://www.martindale.com/products-liability-law/article_Clausen-Miller-PC_247060.htm

Reis, J., (2015) “Expert Challenges and the Revised NFPA 1033,” *Fire and Arson Investigator*, July 2015.
https://s3.amazonaws.com/v3-app_crowdc/assets/1/15/15b42140544b5aa1/1033_Challenges_by_Reis_July_2015_FAI.original.1458932668.pdf

Risinger, D. M., (2000) “Navigating Expert Reliability: Are Criminal Standards of Certainty Being Left on the Dock?” 64 ALB. L. REV. 99, 101, 104.
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=251033.

Thompson v. Whirlpool Corp., (2008) U. S. Dist. Lexus 38968 (W. D. Wash. May 13, 2008.)

Young v. Allstate Insurance Company, (2010) U. S. District Lexus 14514 (E. D. Mo., February 19, 2010).

4. THE PRINCIPLES OF SCIENCE AND INTERPRETING SCIENTIFIC DATA

4-1 The Scientific Method

The application of formal methodologies to the investigation of scientific phenomena has a long history. A recognition of this history and its application to fire phenomena is of particular importance to understanding the scientific nature of fire investigation.

In the days of Aristotle, argument was the method used to "find truth". As methods of observation and data gathering advanced, the use of argument was recognized as not being a reliable method for coming to science-based conclusions. In 1620, a work by Francis Bacon, *The New System*, described a new process of inquiry, in which he wrote, "Argumentation cannot suffice for the discovery of new work since the subtlety of nature is greater many times than the subtlety of argument" [Sagan 1995]. Widely used since the 17th century, this "scientific method" broadly involves systematic observation and data collection, possibly including measurement and experimentation, leading to the formulation, testing, and modification of hypotheses.

The application of science to fire has its roots in the Christmas lectures of Michael Faraday to the Royal Institute in London beginning in 1848. *The Chemical History of a Candle* was the title of a series of six lectures given by Faraday for young people. The lectures examined the chemistry and physics of flames. Through careful observation and analysis, Faraday was able to develop an understanding of fire phenomena and then present that understanding in his lectures using several demonstrations [Faraday 1861].

The scientific method is a process of inquiry and analysis. It is a way of thinking. It is a set of techniques for testing the validity of ideas. In its most basic form, we all learned and practiced this method in high school science class. Indeed, children now learn the scientific method in elementary school.

4-2 Fire Investigation – Basic Methodology

Fire dynamics is a term commonly used to define the study of fire behavior. While fire dynamics research was rapidly developing in the 1970s and 1980s, little, if any, of that research, was being used by fire investigators. Many fire investigators of that time refused to think of themselves as a scientist; thinking that still exists to some extent today. There were, however, those who recognized the need to conduct fire investigations more scientifically.

In 1985, a group of people was convened by the National Fire Protection Association and charged with developing a document to assist those involved in fire investigations. After seven years of development by a thirty-member committee (the NFPA 921 Technical Committee) representing the broad interests involved in fire investigation, NFPA 921 was published. In 1992, this consensus document turned the fire investigation community on its head by stating that fire investigation was, at least in part, a scientific endeavor [NFPA 2021].[18] Since that first edition in 1992, NFPA 921 has contained a chapter titled Basic Methodology.

In each of the nine editions since 1992 (the 2021 edition is the most recently released), the Basic Methodology chapter has articulated the need for a systematic approach to fire investigation. The systematic approach recommended by NFPA 921 is "based on the scientific method, which is used in the physical sciences." NFPA 921 goes on to say that the scientific method "is a principle of inquiry that forms the basis for legitimate scientific and engineering processes, **including** fire incident investigation." (**emphasis** added). NFPA 921 expands this recommendation by outlining the steps involved in the scientific method and detailing how those steps are applied to a fire investigation.

[18] The 1992 through 1998 editions of NFPA 921 described fire investigation as "complex endeavor involving both art and science." From 2001 onward, the description was changed to "a complex endeavor involving skill, technology, knowledge and science."

While the membership of the NFPA 921 Technical Committee has changed through the ten editions, the description of the scientific method applied to fire investigation has remained a core part of the document since the first edition in 1992. To assist the reader of NFPA 921 in understanding this method, Figure 4.1 has been used to depict this methodology visually since the 1998 edition.

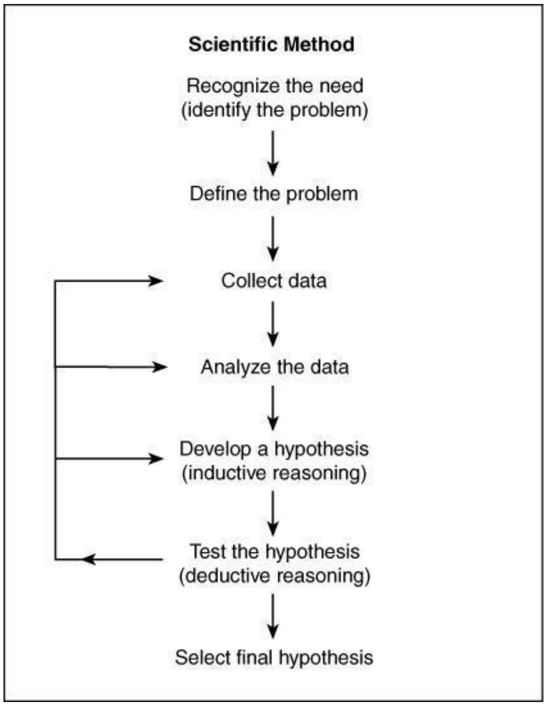

Figure 4.1 Diagram of the Scientific Method from NFPA 921
(copyrightrequests@nfpa.org)

Applied to fire investigation, recognizing the need involves recognizing the fact that a fire has occurred and that there is a desire to prevent similar fires in the future. How this "problem" can be solved is to conduct a proper fire investigation. In the most basic sense, fire investigation is a two-step process. An investigator first determines the location where the fire started – the origin. Then the investigator determines how the fire started – the cause.

NFPA 921 makes clear that this scientific method is iterative. The hypothesis testing process must be continued until all realistic hypotheses have been tested.

There may be numerous hypotheses developed concerning any individual fire incident. Several different investigators will often be involved in developing hypotheses for a particular investigation. This is a function of the investigators' training, experience and expertise as well as their role in the investigation. The hypotheses developed, and how they relate to the incident, may be formed to explain such issues as origin, ignition sequence, fire cause or causes, issues related to damages and casualties, the functioning of fire detection and suppression systems, and the performance of building systems.

It is important for investigators to consider all feasible alternate hypotheses. Consideration of alternate hypotheses, without regard to the initial assessment of likelihood, will help the investigator to reduce the impact of cognitive biases. These biases can never be eliminated, even if the investigator is consciously aware of their existence [Heuer 1999].

4-3 Origin Determination

Origin determination is generally the first step in a fire investigation. A fire investigator should begin with the presumption that the origin is undetermined. If the fire is in a building, for example, anywhere in the entire building could have been the origin. The investigator then utilizes a process that involves identifying the physical location where the fire started and narrowing that location to the smallest area possible. In many fire events, the "room of origin" is determinable with relative certainty. If the fire destroys the entire building, the smallest area determinable may be the building. The "point of origin" is the smallest area. It is that spot where the fuel and heat source come together in such a way that a fire began. The size of the area of origin that can be determined will vary based on the specifics of the incident and the data available for collection. Narrowing the area of origin to a "point of origin" may not be possible.

Figure 4.2 shows the scientific method as applied to fire origin determination and includes elements of each step that should be considered by the fire investigator.

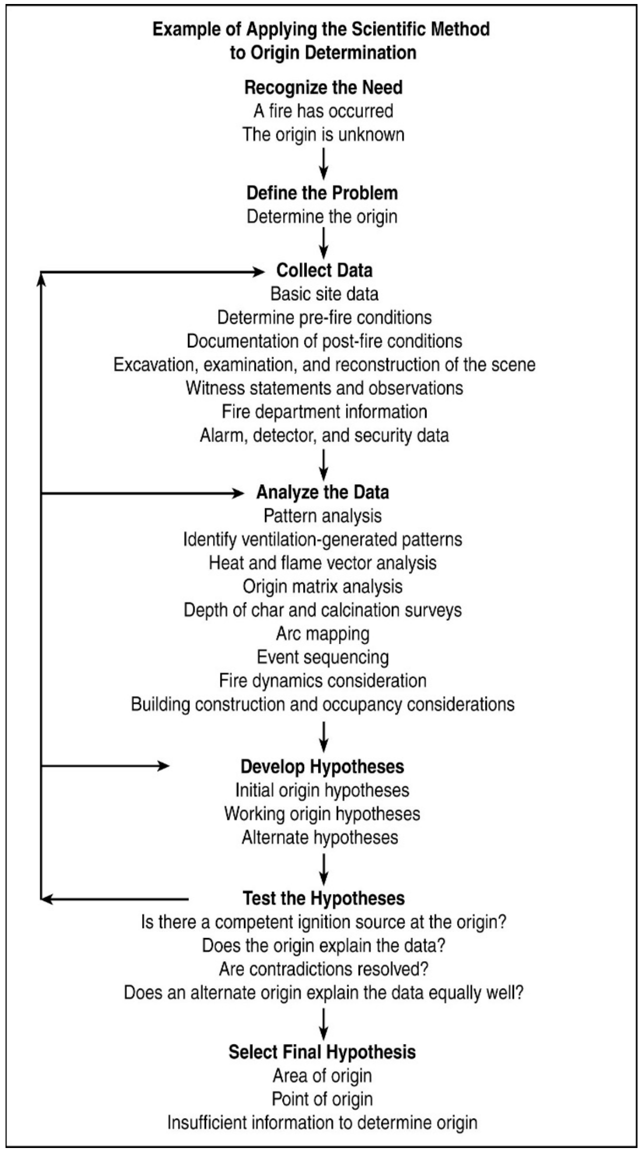

Figure 4.2 – The Scientific Method applied to the question of origin determination

The process of determining the origin first involves the collection of origin-specific data. Pre-fire conditions, the reconstruction of fuel packages, and the understanding of the ventilation conditions are key pieces of data. Once that information has been established, the investigator then analyzes the patterns created by the fire and develops hypotheses about the growth and spread of the fire. By understanding how the fire grew, the investigator can develop hypotheses as to where the fire started.

Fire investigators determine the origin from interviewing witnesses, examining the scene, and putting that data into context with data that they collect from other sources. For example, the investigators will try to obtain data about where the fire was observed when it was still small. They will try to collect data from witnesses who had knowledge about the scene and what activities were taking place.

While non-scene data is important, the data gained from the examination of the scene is usually essential to determine the origin. Some examples of data that are only available at the scene are: patterns of damage, the status of windows and doors, actual dimensions of the structure, arcing damage on electrical wiring, positions of valves and switches, and fire debris samples that can be used for laboratory examinations.

The procedure recommended for scene examinations in NFPA 921 is to start the scene examination from areas of less damage and progress towards areas with the most damage. This practice of progressing from the least to the most damage is part of a systematic approach and is not because the area of most damage is the fire origin. There are many reasons why an area could have more damage than the origin, such as there was more fuel at that location, there was better ventilation at that location, or perhaps the fire department concentrated suppression efforts somewhere else.

As investigators are performing the scene examination, they consider each area and use their knowledge of fire science to determine whether a fire that started in that location could have spread to the other areas that sustained fire damage, or if the damage in that area could have been created by a fire starting somewhere else. To perform this assessment, investigators need to collect information about the building geometry and construction materials as well as information about the location of building contents and flammable items. Investigators use fire dynamics principles to evaluate fire flows, temperatures, the potential for full room involvement, and other technical knowledge to determine whether each area is a potential origin location. Investigators identify each of these potential origin locations and continue the scene examination to find other potential origin locations.

Recent training exercises and research have revealed that origin determination becomes more difficult if a room has been fully involved in fire for more than a few minutes [Carman 2008, 2010, Tinsley & Gorbett 2012, Cox 2013 Gorbett et al. 2015]. Sometimes the best result that a fire investigator can achieve is identifying the compartment where the fire started.

4-4 Cause Determination

At the outset of an investigation, the cause is undetermined. If the origin remains undetermined, the cause will, in most cases, also remain undetermined. Assuming the origin determination is correct, the cause must lie within the area of origin, unless it has been removed. A large area of origin may encompass numerous potential ignition sources and fuels. A smaller area of origin is likely to encompass fewer. It is at the "point of origin" where a single competent ignition source and first fuel ignited combination is found.

Cause determination involves the process of identifying the possible ignition sources and fuels in the determined area of origin. Once those have been identified, an analysis is conducted to analyze how the fire may have initiated - the circumstances and conditions that allowed the ignition source and fuel to come together. This usually requires the investigators to evaluate information from the fire scene examination as well as the "non-scene data."

Figure 4.3 shows the scientific method as applied to fire cause determination and includes elements of each step that should be considered by the fire investigator.

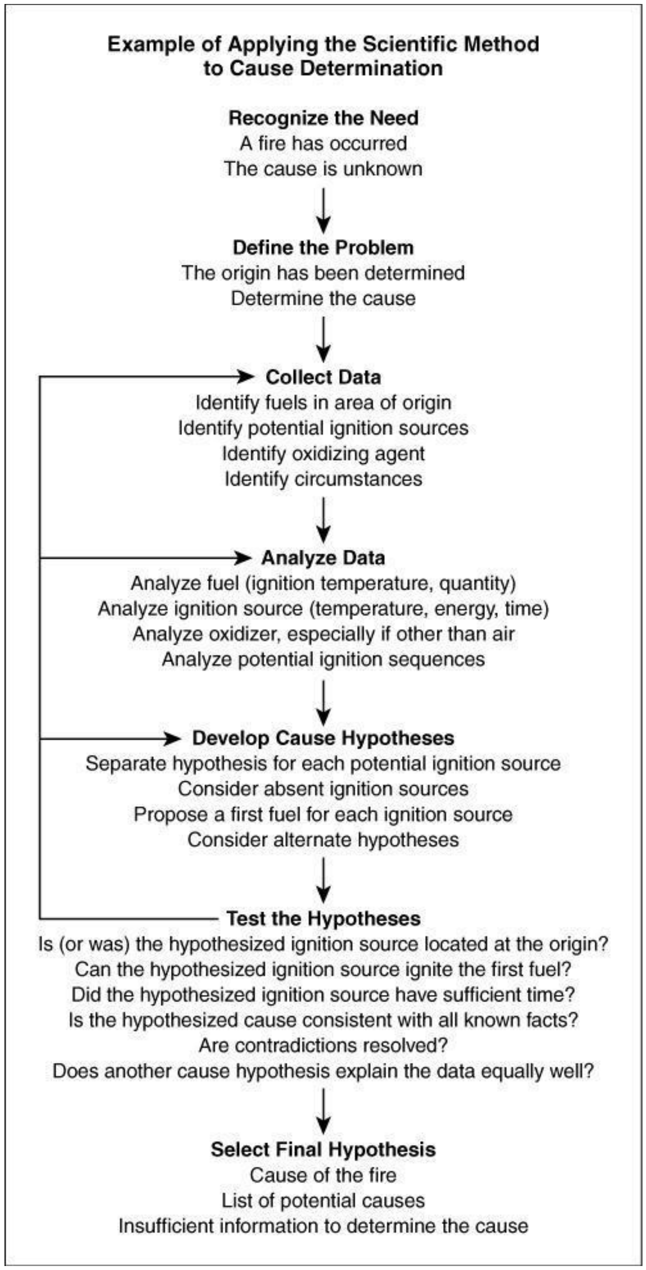

Figure 4.3 – The Scientific Method applied to the question of cause determination

Fire cause is defined as the circumstances, conditions, or agencies that bring a fuel, ignition source, and oxidizer (such as air or oxygen) together resulting in a fire or a combustion explosion [NFPA 2021]. Investigators must identify both the ignition source and the first fuel ignited to define the fire cause. The investigators must also identify how the ignition source was able to cause ignition of the fuel. For example, when an investigator identifies a book of matches as the ignition source and newspaper as the first fuel, they must also show, using data, how the matches ignited the newspaper.

Investigators then evaluate whether each of the potential ignition sources could be the actual fire cause. This can be a difficult and time-consuming process, involving a pairwise comparison of potential ignition sources with potential first fuels. The fire investigator must consider for each pair whether the proposed ignition source is competent to ignite the proposed first fuel, whether it was close enough and whether there is evidence that such ignition occurred. To perform this evaluation, the investigators use their knowledge and collected data as well as the input from other experts. For example, if a potential fire cause was an electrical appliance, the investigator may require input from an appliance expert. The considerations used in determining the ignition source and first fuel should be documented in writing.

The accuracy of fire cause determination is dependent on the investigators identifying the correct origin of the fire. If the investigators are searching for ignition sources in the wrong location, they will not be able to determine the cause of the fire accurately. If the wrong area of origin is determined, the investigators could identify the wrong fire cause or decide that they could not find the fire cause.

Throughout the process of cause determination, investigators are following the scientific method. As they are receiving additional information, they are constantly evaluating their hypotheses against the available data. If the hypothesis about the fire cause does not fit with the available data, the investigator must continue to evaluate other possible fire causes and if none are found to look for fire causes and to reevaluate whether the correct origin location was identified.

NFPA 921 makes clear that fuel by itself or an ignition source by itself does not create a fire. It is the action of the ignition source on the first material ignited that causes the fire. As outlined in the flow chart, a proper cause hypothesis must be developed from an understanding of the science behind the interaction between the heat and the fuel. Fire investigators need to understand this interaction.

4-5 Cause Classification

Once the investigators have determined the fire cause, NFPA 921, through the 2017 edition, provided guidance for the classification of the fire cause. The four fire cause classifications were undetermined, natural, accidental, or incendiary. Determining the cause and the classification of the fire cause are separate processes. Classification of the fire cause is used for assignment of responsibility, for statistical purposes, and reporting purposes. There is no requirement in NFPA 921 to classify the fire cause. The OSAC Fire and Explosion Investigation Subcommittee proposed the elimination of the cause classification chapter in NFPA 921 for the 2021 edition revision cycle. The four fire cause classifications are inconsistent with the existing National Fire Incident Reporting System (NFIRS) cause classifications, and the process of classification adds nothing to the process of assignment of responsibility. The Technical Committee accepted the OSAC Subcommittee's suggestion that the chapter on Cause Classification be eliminated.

4-6 Hypothesis Development

The NFPA 921 Technical Committee has included clear statements about what constitutes valid hypotheses. The following statements exhibit the Committee's position on the development and testing of hypotheses.

> *"These hypotheses should be based solely on the empirical data that the investigator has collected through observation and then developed into explanations for the event, which are based upon the investigator's knowledge, training, experience, and expertise."*
>
> *"The investigator does not have a valid or reliable conclusion unless the hypothesis can stand the test of careful and serious challenge."*
>
> *"If the hypothesis is refuted or not supported, it should be discarded, and alternate hypotheses should be developed and tested."*

*"The testing process needs to be continued until all feasible hypotheses have been tested, and one is determined to be **uniquely** consistent with the facts and with the principles of science."[**emphasis** added]*

"Any hypothesis that is incapable of being tested either physically or analytically is an invalid hypothesis. A hypothesis developed based on the absence of data is an example of a hypothesis that is incapable of being tested. The inability to refute a hypothesis does not mean that the hypothesis is true."

"If no hypothesis can withstand an examination by deductive reasoning, the issue should be considered undetermined."

This last statement is particularly telling of the process of fire investigation. Given the destructive nature of fire and the effects of extinguishing the fire, data is lost or destroyed. In many cases, pieces of the puzzle cannot be found. If enough of those pieces of the puzzle are missing, a specific origin and cause of the fire may be indeterminable. An origin and a cause may be undetermined if no hypothesis can be sustained. The origin and cause may also be undetermined if multiple hypotheses can be reached based on the data analyzed.

4-7 Reliability and Validity

There has been much discussion in the forensic science community about the reliability and validity of methods or procedures. Some of this discussion comes about because the terms have different meanings to different groups of forensic investigators. Consideration also needs to be given to whether it is the data itself or the conclusions from the data that is the focus.

Many forensic endeavors involve laboratory analysis. In these applications, reliability means repeatability or reproducibility of measurements or conclusions, while validity refers to the accuracy of the measurements or conclusions. In non-laboratory settings, conclusions are rendered based on data, informed by an investigator's experience and training. While it is possible to assess the reliability of such judgments by assessing intra- and inter-investigator agreement, validity is much more difficult to evaluate.

Issues of reliability and validity enter the field of fire investigation in several ways. One is in the collection of facts and data. The reliability of data, particularly things like the observations of witnesses, need to be considered in any investigation. Given the nature of fire and explosion events, data is often destroyed or lost due to the event itself or because of the efforts of first responders. The reliability and "value" of the data needs to be considered. When the data gathered is inconsistent, the investigator must report the inconsistency and resolve if scientifically justified.

Additionally, following the scientific method, hypotheses must be testable. A hypothesis that is based on the absence of data cannot be tested and should be discarded. Additionally, the investigator must understand the difference between evidence of absence and absence of evidence. Just because there is "no evidence" to disprove a hypothesis, does not mean that the hypothesis is supported.

Conclusions drawn by investigators are based on the analysis of data — incorrect analysis results in incorrect conclusions. The vast majority of fire investigators base opinions about the origin of a fire or explosion on the interpretation of patterns—the resultant damage or lack of damage caused by the event. In a small well-contained fire, these patterns typically are easily discernible, and their analysis is, for the most part, straightforward. As the damage from the event increases, the interpretation of patterns is much less straightforward. Initial patterns can be obscured, new patterns can be created in areas away from the origin, and patterns can be destroyed by the fire or firefighting operations, all of which make the analysis and interpretation of patterns more difficult and potentially unreliable.

Validity issues also come about due to the training and experience of the investigator. The application of complex scientific principles, based on physics and chemistry, is often made by investigators with little or no training in these disciplines, which can lead to errors.

The measure of whether expert opinion testimony is allowed by some courts considers reliability and validity as part of the evaluation. Rule 702 of the Federal Rules of Evidence requires judges to evaluate, in part, the following when admitting expert testimony:

- the testimony is based upon sufficient facts or data,
- the testimony is the product of reliable principles and methods, and
- the witness has applied the principles and methods reliably to the facts of the case.

There is little in the way of procedures outlining how a fire investigator evaluates data. More procedures need to be developed and researched (see Chapter 7). As one example, much of a typical origin investigation relies on the interpretation of patterns left by the fire. A scientific study [Gorbett et al. 2017] has shown that a defined procedure to identify origin determination based on fire patterns increases reliability and validity.

4-8 Uncertainty and Error

Scientific data and processes (as well as nonscientific evidence) are subject to a variety of sources of error. A key task for fire investigators conducting a scientific study is to identify as many sources of error as possible, to control or to eliminate as many as possible, and to estimate the magnitude of remaining errors so that the conclusions drawn from the study can be evaluated.

Misinterpreting data, such as how a particular pattern was created, may lead to error in an origin determination. Failure to consider the heat energy required to raise a fuel to its ignition temperature may lead to error in a cause determination. Failing to resolve inconsistent data will also likely result in an error.

In the fire investigation community, the issues of error are often not evaluated until a case is litigated. Challenge occurs most often in this setting. There is a need for error to be identified and corrected in all fire investigations. Most of this country’s fire codes evolve based on the lessons learned from fires. Incorrect conclusions drawn have the potential to cause inappropriate requirements in codes and standards.

In articulating opinions, it is incumbent upon the investigator to eliminate error to the extent possible and to clearly articulate any uncertainty.

4-9 Conclusions

Fire and explosion investigation must be recognized as a scientific endeavor and practiced as such. This should involve requiring investigators to articulate their scientific reasoning. It should also involve requiring investigators to enumerate the possible origin and cause hypotheses that were developed and showing how particular hypotheses were eliminated until a hypothesis that is **uniquely** consistent with the facts and the principles of science was reached. Requiring rigorous, independent review other than through the adversarial process of the courts is one method of assuring technically sound decisions in those investigations with the highest consequences.

REFERENCES

Faraday, Michael (1861). W. Crookes, ed. A Course of Six Lectures on the Chemical History of a Candle. Griffin, Bohn & Co. ISBN 1-4255-1974-1. https://archive.org/details/chemicalhistoryo00faraiala

Federal Rules of Evidence, Rule 702, https://www.law.cornell.edu/rules/fre/rule_702

Gorbett G, Meacham B, Wood C, Dembsey N (2017) Structure and Evaluation of the Process for Origin Determination in Compartment Fires, Fire Technology 53:301. https://doi.org/10.1007/s10694-015-0553-3

Heuer, R., (1999) Psychology of Intelligence Analysis, Center for the Study of Intelligence, U.S. Central Intelligence Agency, 1999, https://www.cia.gov/static/9a5f1162fd0932c29bfed1c030edf4ae/Pyschology-of-Intelligence-Analysis.pdf

NFPA (2021), NFPA 921, Guide for Fire and Explosion Investigations, NFPA, Quincy, MA.
http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=921

Sagan, C (1997) The Demon-Haunted World: Science as a candle in the dark. Ballantine Books.
http://www.metaphysicspirit.com/books/The%20Demon-Haunted%20World.pdf

5. DESCRIPTIONS OF SOME FIRE AND EXPLOSION INVESTIGATION DISCIPLINES

This chapter describes the techniques and processes used during a typical fire investigation. It is organized according to the Job Performance Requirements (JPR's) as laid out in NFPA 1033, *Standard for Professional Qualifications for Fire Investigator*:

1. Scene Examination
2. Documenting the Scene
3. Evidence Collection/Preservation
4. Interviews
5. Post-Incident Investigation (non-scene)
6. Presentations (written and verbal reports, testimony)

This description is focused on the current state of fire investigation as it is practiced today and identifies some deficiencies in those practices or referenced guides and standards.

5-1 Scene Examination

The fire scene is examined to understand the condition of the property before the fire and the effects of the fire upon the property. The scene data collected is in support of determining the origin and development of the fire as well as the cause of the fire.

Fire scenes are generally observed from the perimeter to gain a global view of the damage and assess the extent of the fire-damaged area that will require interior examination. The perimeter survey also generally allows an initial assessment of the safety issues at the scene and the need for perimeter controls. After these initial surveys, a more detailed examination of fire effects is undertaken.

The patterns of fire effects are key observations that can be analyzed to determine the origin and spread of the fire. The fire effects that create the damage patterns include:

1. Loss of mass
2. Charring
3. Spalling
4. Oxidation
5. Melting and alloying
6. Thermal expansion and deformation
7. Smoke deposition
8. Clean burn
9. Calcination
10. Glass breaking and deformation
11. Victim Injuries
12. Electrical arc melting

These fire effects are the result of thermal insults ranging from merely hot gases to direct flame contact. Understanding the fire effects upon the wide range of materials present in the built environment is key to understanding the fire exposure that creates fire effects and the development of the fire. As is apparent from the list of fire effects above, there is a wide range of potential fire effects and the nature of these fire effects is directly determined by the chemical and physical nature of each of the materials present.

Field methods for determining fire effects and their patterns include visual/photography, and depth measurements (char and calcination). Simple observation is not always a suitable means of identifying patterns. For instance, blackening can occur due to smoke deposition or thermal decomposition of the underlying material. Loss of coatings like paper or plastic films can further complicate the identification of patterns of damage. Apparent clean burn patterns can also result from shedding of a surface coating.

It is common for fire investigators to identify a fire pattern where they have not identified the underlying fire effects that caused the various parts of the overall pattern. This compromises the utility of pattern identification. Close examination/photography or even microscopy of a local surface will help identify the fire effects as will superficial delayering of the surface.

Electrical activity patterns (arc mapping) require close scrutiny of the entirety of the electrical system and devices within the fire area. Wide photographs can provide overall documentation of where the electrical activity is but close up photography is needed to document the details of the electrical activity.

Similarly, identification of potential ignition sources is not achievable with only wide view photographs. Identification of electrical activity and potential ignition sources requires a highly detailed examination of the fire scene, sifting the relevant artifacts from the bulk of the debris. Sieves and magnets are often required.

Fire scene reconstruction is an important investigative tool. The large quantities of fire debris in the fire scene obscure the original configuration of objects, and reconstruction allows the pre-fire configuration to be established and puts the fire effects on different objects in context for comparison. The reconstruction process identifies patterns in damage that cannot be observed in the fire scene as found. The process of debris removal and reconstruction is an involved and time-consuming task, but one that provides pattern data for analysis.

Fire pattern analysis is the application of fire dynamics to understand the fire development consistent with the fire effects and patterns. The analysis is not a static analysis but rather seeks to identify the sequence of the formation of fire effects and patterns. The detailed nature of the fire load throughout the scene and the ventilation openings has significant impacts on the fire effects and patterns that need to be incorporated into the fire dynamics analysis.

Scene examination for the determination of the fire cause includes identification of potential ignition sources and the fuels which are available to be impacted by these potential ignition sources. Failures that cause fires may be localized to an area the size of a grain of rice or smaller.

Identification of evidence of such failures involves detailed examinations that may require many hours of scene work. Often the results of a scene examination include the collection of items for further laboratory analysis to understand the role of the potential ignition source in the fire scenario. Since all potential ignition sources within the area of origin need to be considered in the formation of cause hypotheses, this painstaking work is an essential part of the fire scene examination.

In explosion events, the damage to and displacement of items are critical to understanding the severity of the explosion and its origin. An understanding of the damage to and trajectory of items by the impulse loading of the explosion is key to understanding the explosion event. Frequently, understanding explosion damage is complicated by the effects of the subsequent fire.

5-2 Documenting the Scene

Fire investigators are required to receive minimum training in the methodology of fire scene documentation and must have specific abilities to document scenes. However, the specific amount or type of training required is not quantified by any single standard. Minimally, at least one fire investigator is obligated to sufficiently document a given fire scene.

There is substantial guidance within authoritative texts in the field as to how to document the fire scene investigation. For example, the evidence is documented in place, fire scenes are photographed, and measurements are taken to assist with scene reconstruction. However, the amount and quality of fire scene documentation depend on the investigator's or expert's role (or that of their employer). This role also drives what type of report, if any, will be produced to memorialize the investigation. While there is no universal mandate to write a report, one may be required before an investigator is allowed to testify to the results of an investigation. In the federal courts and many other jurisdictions, testimony will be subject to exclusion if the fire investigator has not prepared a report. For more information on reporting requirements, see Chapter 3-3.

The act of documenting the scene and recording data during the investigation is the first step, while the second step is the production of a report. The report typically provides a synopsis and analysis of the investigation and relies, in part, on the data documented while on the fire scene. However, while the scene will always be documented to some degree, the production of a report is not a given. There are some agencies whose documentation is so poor that it does not even include a diagram, and the photographic documentation is insufficient for a subsequent investigator to understand the fire scene or its investigation.

The degree of scene documentation is driven by the need to preserve data for later analysis, not necessarily for reporting requirements. The investigators are charged with casting a wide net — they may not know at the time of the scene investigation what will be important data and therefore should document, within reason, all data related to the fire scene and specific incident. Like other fire investigation data, investigators should consider the data gained from the scene within the context of other data (such as interviews) developed during the investigation. The perceived importance of scene data in fire investigation may change. It is not unusual for data collected from the scene to be unimportant early in the investigation and then to become important later (or vice versa).

Fire investigators typically document data which may be subsequently reviewed, analyzed, and summarized into an origin and cause report. This report will be used to communicate findings and the bases for those findings.

Fire investigators typically examine a fire scene from the exterior to the interior, documenting items of interest (data) as they proceed. The documentation should illustrate a systematic approach to the fire investigation. Documentation of the scene may require the use of special tools or accessing areas outside of the scene. In larger fire scenes, involving a team of investigators, documentation responsibilities may be divided. One investigator may be designated to be the photographer, another investigator tasked to take notes, and yet a third investigator is designated to map the scene forensically. Safety considerations may affect the ability to document a scene thoroughly. Weather and lighting conditions also play a role and may dictate when and where an investigator can document the scene.

Photography is perhaps the most important technique used to document the scene. NFPA 921 [2021] Section 16.2.1 recognizes that photographs are:

> *"… the most efficient and effective reminders of what the investigator saw while at the scene. Important items that were documented by photography may become more evident upon review of the photographs or videos. Photographs and video are necessary to substantiate the investigator's observations".*

Photography should be done in conjunction with a photograph log to describe each photograph and its perspective accurately. There is guidance in NFPA 921 on how to create a photo log.

Note-taking is another standard method of documentation and is widely used. There is no standard as to the extent of notes, content, or format. As NFPA 921 Section 16.3.1 states,

> *"The use of forms is not required in data collection; however, some forms have been developed to assist the investigator in the collection of data. These example forms and the information documented are not designed to constitute the report but instead provide a means to gather data that may be helpful in reaching conclusions so that a report can be prepared. (See A.16.3.2.)".*

Notes should be retained. The failure to retain notes hinders the ability of other experts to analyze the same set of data documented and analyzed by the initial fire investigator. Additionally, the destruction of notes (which are evidence) can leave the impression that the investigator is hiding something.

Diagrams and sketches are used to assist investigators in understanding fire growth and development. These may be later used to communicate findings, to explain photographs and evidence, or to assist in witness or suspect interviews. NFPA 1033 identifies that a requisite skill to be a fire investigator is to be capable of producing a sketch and diagram of a fire scene. NFPA 921 provides guidance on what to include in the legend and how best to label a diagram.

Documenting Patterns

Fire patterns are some of the most important data to document. The foundation of fire scene investigations consists of identifying, recognizing, documenting, and interpreting fire patterns. These patterns may yield data that helps to establish area(s) of origin and to identify potential ignition sources. Per NFPA 921, the investigator will use three factors, including fire pattern analysis, to identify an area of origin before identifying a cause. The analysis of patterns will be aided by "reconstruction" of the scene by investigators. This reconstruction varies in magnitude and generally consists of clearing debris and placing significant fuel packages back in their pre-fire positions to visualize fire patterns and undamaged areas better. Patterns are documented through photography but may also be documented through notes, measurements, and sketches or diagrams. In rare circumstances, a pattern may be collected as evidence by taking the underlying substrate into evidence.

Documenting Physical Evidence

Fire investigators will also document physical evidence as it is identified, collected, and examined. Not only is there a legal requirement to do so (i.e., chain of custody documentation and evidence logs), but there is an obligation to do so since the evidence may not be preserved beyond the scene examination. There is a wide variety of items in a fire scene that could be considered evidence, such as debris, patterns, appliances, containers, blood spatter, and NFPA 921 provides guidance on when to properly document much of these specific items of evidence. During the fire scene investigation, investigators are expected to identify the evidence and document it in place as well as in context with the rest of the scene. The processing of the evidence, whether that be collection or removal of other debris around it, is further documented. The chain of custody is documented as well before leaving the scene. Done correctly, this will allow for third-party analysis of the evidence and protection against charges of spoliation.

Documenting Structures and Building Systems

Investigators will often need to evaluate a structure's construction as well as the systems contained within them. The design and construction of a structure will often dictate fire growth. Components within the structure, such as the electrical or HVAC systems, have to be considered when assessing ignition sources as well as their influence on fire growth. It is critical for investigators to have a thorough understanding of these elements if they are to render accurate opinions about the origin and cause of a fire. Investigators will typically use photography, note-taking, and diagramming to document the type of construction, the materials used in construction, and the compartmentation within it. Also, investigators document various pieces of the electrical service, natural gas or propane service, HVAC components, alarm systems, and fire suppression systems. This effort often will include arc mapping, which involves the identification and documentation of a specific type of pattern found on electrical conductors.

Documenting Personnel and Processes

Investigators may document personnel processing the fire scene as well as scene investigation processes. This is usually done through photographs and notes. For example, investigators may document the use of an Ignitable Liquid Detection Canine team, the use of heavy equipment, and when witnesses are walked through the scene.

The purpose of documenting these activities is to allow investigators to create a narrative as to how they employed a systematic approach to their fire investigation. This preserves their ability to explain how their scene investigation developed and proceeded.

Documenting Testing

Fire investigators may conduct field tests in furtherance of testing their origin and cause hypotheses. As with other processes, these tests are usually documented with photography, video, and notes. This documentation will serve to strengthen hypothesis development and testing, as well as any conclusions based on the test data.

Best Practices Recommended by NFPA 921

NFPA 921 provides guidance on how and when to document a fire investigation. Consideration is given to the fact that some investigators may not have had an opportunity to access the scene. NFPA 921 puts the responsibility of properly documenting a scene on at least one party so that other parties can use the same data to conduct their investigation successfully. As Section 4.4.3.3 states,

> *"In any incident scene investigation, it is necessary for at least one individual/organization to conduct an examination of the incident scene for the purpose of data collection and documentation. While it is preferable that all subsequent investigators have the opportunity to conduct an independent examination of the incident scene, in practice, not every scene is available at the time of the assignment. The use of previously collected data from a properly documented scene can be used successfully in an analysis of the incident to reach valid conclusions through the appropriate use of the scientific method".*

Section 4.4.3.4 further states,

> *"Improper scene documentation can impair the opportunity of other interested parties to obtain the same evidentiary value from the data. This potential impairment underscores the importance of performing comprehensive scene documentation and data collection".*

NFPA 921 devotes an entire chapter to scene documentation, describing how the goal of this documentation is to make an accurate recording of the investigation that will, in turn, allow investigators to recall and communicate their findings, detail their analysis and basis for opinions, and preserve data for others to use. The chapter details the recommended techniques for a variety of commonly used documentation techniques such as photography, note-taking, and diagramming. The chapter does not quantify the amount of documentation needed, nor its format.

NFPA 921 also provides explicit guidance in another ten chapters for documenting specific areas of the fire scene investigation. These chapters address things such as Building Systems, Active Fire Protection Systems, Electricity and Fire, Physical Evidence, Appliances, Motor Vehicle Fires, Explosions, Marine Fires, and Wildfire Investigations.

A fire scene investigation is a complex endeavor, requiring the collection and compilation of data, and subsequent analysis of that data. Fire investigators have to skillfully use their knowledge of science and technology to collect and evaluate this data properly. Accurate documentation of this data lends itself to rigorous hypothesis testing and accurate conclusions, whereas the poorly documented scene can lead to erroneous analysis. In short, scene documentation is the foundation for proper fire pattern analysis, hypothesis development and testing, failure analysis, and testimony.

Complete and thorough documentation of scene data is important because the relevance and importance of that data may only be understood at a later time. Data used to form a conclusion about the origin and cause of a particular fire are drawn from many different sources. These include sources outside (e.g., a witness interview) and inside the actual fire scene (e.g., fire patterns). This documentation will not only be used by the fire investigator to communicate their analyses and conclusions but will be used by others to develop their analyses and conclusions.

Assessment of Current Practice

The documentation of fire scene data is inconsistent throughout the country, governed by few standards, and may be mostly dictated by the role of the investigator or expert. Consensus standards exist, for example, ASTM E1188, which provides minimum documentation requirements for forensic science disciplines. It is a sad fact that many fire investigators are unaware of ASTM E1188 or see no need to comply with this generally accepted standard.

Documentation of the scene can be considered a two-part process. The act of documenting the scene and recording data during the investigation is the first step, while the second step is the production of a report. Reports are covered extensively in Chapter 3. The report typically provides a synopsis and analysis of the investigation. Though inextricably related, these two steps can be considered separately.

There are some broad mandates to report content, but these are so unspecific that there is no consistency among agencies (public or private) that produce reports. Beyond the obvious instruction to detail data supporting conclusions in origin and cause reports, there is a deliberate silence by authoritative texts in the field as to what should specifically be contained in an origin and cause report. NFPA 921 *Guide for Fire and Explosion Investigations* [NFPA 2021], Section 16.5, states,

> "*The final step in the documentation of the investigation may be the preparation and submittal of a report. The format and content of the report will depend on the needs of the organization or client on whose behalf the investigation was performed. Therefore, no report format is prescribed here.*"

To complicate matters, often the nature of fire litigation produces opposing parties. These investigators or experts may enter a particular fire investigation (or associated legal action) at different points in time. Therefore, the actual fire scene may not be available to all parties for examination. One or more parties may rely on the original investigating agency's documentation to conduct their origin and cause investigation to formulate their own opinions.

Recent advances in technology (e.g., digital cameras, laser scanning, unmanned aerial vehicles) have made it easier to document fire scene investigations. Unfortunately, this does not necessarily translate to better-documented fire scene investigations. The lack of mandated scene documentation training and protocols may account for this slow progress.

5-3 Evidence Collection/Preservation

According to NFPA 921, physical evidence can generally be defined as

> *"any physical or tangible item that tends to prove or disprove a particular fact."*

Without proper evidence documentation, collection, and preservation procedures in place, the value of any physical evidence that has been collected can be highly diminished.

Typically, documentation, collection, and preservation of evidence from a fire or an explosion scene are the responsibility of the fire investigator. Therefore, fire investigators need to have an appreciation of the value of identifying, documenting, protecting, collecting, and preserving physical evidence before beginning an investigation. There is a wide range of sources of information to gain this fundamental knowledge [NFPA 921, ASTM E1188, ASTM E1459]. However, knowledge of the evidence collection process is not sufficient. Investigators typically train under another investigator to gain practical experience in correct evidence handling procedures.

Investigators need to also have an understanding of their particular laboratory's capabilities in regards to an examination of physical evidence. The best way to gain this understanding is to visit and talk with laboratory examiners before submitting evidence.

Evidence Identification

Fire scene evidence, in general, is not like evidence from other crime scenes. The fire and explosion scene is a harsh environment. Heat, flame, smoke, and high pressures in a fire and explosion scene are likely to damage or alter physical evidence. Given this possibility, the investigator seeking to collect physical evidence needs first to identify what physical evidence may be present at a fire or explosion scene.

Ignitable liquid detection canines (IGL canines) have been used as a tool for assisting the fire investigator in locating and identifying physical evidence for ignitable liquid residue analysis by a laboratory. When used properly, a proficient IGL canine team can be a valuable tool for fire investigators. If used in the search for evidence, it is important for the fire investigator to understand the capabilities and limitations of IGL canines [CADA 2012].

It is important to understand the type of evidence that is being collected. For example, when collecting fire debris for ignitable liquid examinations, the investigator should be familiar with the properties of the ignitable liquids. Some soils contain microbes that could potentially degrade ignitable liquids. This can be mitigated by freezing or refrigerating the soil sample. Similar problems arise due to mold formation on fire scene surfaces.

One important aspect of fire and explosion evidence is the need to collect comparison samples. Given the prevalence of ignitable liquids and consumer products that are manufactured from petroleum distillates, investigators need to collect comparison samples of materials from an area that can reasonably be expected to be protected from the fire. For example, when collecting carpet or other flooring samples that are suspected of containing ignitable liquids, the investigator should collect the same flooring samples from the scene that are not expected to contain ignitable liquid residue to serve as a comparison sample. This allows the laboratory examiners to evaluate the chemical contributions from the background.

To prevent cross-contamination of evidence samples, proper protocols for the decontamination of boots and tools should be followed. The investigator should have a general awareness of the consequences of cross-contamination.

Protection of Evidence

The protection of potential fire and explosion evidence is the responsibility of everyone at the scene. The fire investigator is not the only one that bears this responsibility; first responders that are involved in fire suppression and overhaul efforts should also be aware of correct procedures to protect evidence. Personnel at a fire scene should at all times be aware of the need to protect the evidence and to preserve the integrity of each item by protecting it from loss, contamination, and degradation. Once potential evidence is identified, the investigator or responsible party should take steps to protect the evidence. ASTM Standards E860 and E1188 should be consulted for more specific procedures for protecting potential evidence.

Storage and Disposal of Evidence

Once the evidence has been properly collected and packaged, the investigator should submit the evidence for examination as soon as practical. In the time between collection and submission, it is important to properly store evidence. Procedures for storage of the evidence should account for the type of evidence, specific preservation requirements, managing access to the evidence, and the temperature of storage facilities. When transporting evidence, care should be taken to prevent damage, contamination, or spoliation of the evidence.

Disposal of evidence should follow specific requirements of the investigating agency. Consideration should be given to the statute of limitations, other parties who may have an interest in the evidence or returning the evidence to the original owner.

5-4 Interviews

Interviews are critical in nearly all fire investigations, often providing data necessary and relevant for origin and cause hypothesis development and testing. During fire investigations, interviews are typically conducted of a combination of first responders, the fire discoverers, occupants, witnesses, property owners, and so on. In cases where the fire cause is determined to be incendiary, there may be a custodial or non-custodial suspect interview. Moreover, the interviews may take place over multiple intervals during or after the actual scene investigation.

Interviews identify data helpful to determining fire origin and spread, the configuration of fuels, contents, and compartments, presence and state of ignition sources, state of repair or disrepair of property or equipment, fire timeline, intentional or unintentional acts related to the fire, suppression efforts and tactics, and other useful information. Interviews provide context to other data identified during the fire investigation.

Types of Interviews (custodial and non-custodial)

Fire investigators frequently conduct non-custodial interviews of witnesses to gather data pertinent to the fire investigation. This type of interview is typically limited to issues surrounding origin and cause of the fire. These interviews often occur contemporaneously with the fire investigation, and witnesses may even be on hand at the scene to point things out to investigators. The type of witness will dictate the type of information being solicited, and investigators must be proficient in communicating on technical matters as well as simple issues. An interview with a first responding firefighter will utilize different terminology than that with a passer-by. The interview may consist of several different phases and may occur multiple times as investigators narrow their origin and cause focus.

Custodial interviews, typically of those suspected of setting the fire, can be the most challenging. A custodial interview is not necessarily predicated on an incendiary cause determination. The tactics and preparation for this type of interview are unique. Depending on the jurisdiction, the custodial interview may be undertaken by the fire origin and cause investigator or by law enforcement personnel unrelated to the fire investigation. The recent debate over the bifurcation of roles and responsibilities of fire investigators has challenged the notion that the lead fire investigator should be involved in every interview in a given fire investigation. In custodial interviews of a suspect, at least one of the interviewers should be a fire investigator (not necessarily the lead fire investigator) who is well-versed in fire science as well as that particular fire investigation. This is so that the proper analysis of the suspect's statements can be made, and scientifically challenged if necessary.

In many instances, a canvas of a particular neighborhood will be undertaken. This effort is an attempt to speak with witnesses who have not yet come forward or previously been contacted by investigators. Effective canvasses by trained fire investigators gather more germane information about the fire's origin and spread, as well as its timeline.

Interview Preparation

Fire investigators typically prepare for interviews by reviewing data from the fire scene, analyzing other witness statements, and speaking with other investigators. This preparation is vital for a thorough interview and may include a checklist or use of a questionnaire. In particular, for fire investigators not involved in processing the fire scene, it is imperative that they understand the various hypotheses concerning the origin and cause of the fire. Investigators also use diagrams, pictures, documents, or artifacts to help with interviews.

Difficulties Encountered in Interviews

Fire investigators encounter numerous challenges during interviews. These may include language or cultural barriers, the inability of the investigator to communicate in a non-technical manner, difficulty in conversation with victims, poor environmental conditions when conducting the interview, hostility from the witness, and limited accessibility of the witness. These variables require investigators to be flexible, adaptable, and to have an interview strategy consistent with the witness and the situation. Witnesses may need to be interviewed more than once. In NFPA 1033, it is recognized that investigators must have the skill and ability to, "adjust interviewing strategies based on deductive reasoning…" [NFPA 1033, p. 9]

Some difficulties are self-imposed by investigators. Investigators may miss vital data if they do not properly analyze or follow up on witness statements.

Documentation of Interviews

Interviews, like any other relevant piece of data, must be documented. This typically is done through notes but may also include an audio or video recording. Recordings and notes taken during the interview should be retained. Following the interview, it is typical for a written synopsis to be produced. Also, some investigators will produce a written statement or have the witness write a written statement synopsizing the interview. This written statement is reviewed and corrected by the witness who ultimately signs it.

Analysis of Interviews and Context

Investigators must consider the data gained from the interview within the context of other data developed during the investigation. Many times, the data from the fire scene is consistent with the witness statements. This does not absolve investigators from critically analyzing it. At times there are data from the fire scene or other witnesses which may contradict a witness statement. This does not necessarily mean the witness was untruthful; rather, their perception may have been inaccurate or incomplete. Investigators should attempt to resolve conflicts among the witness statements and the scene or case data.

It is not unusual for data collected from interviews to be irrelevant early in the investigation and then to become relevant later (and vice versa). Because of this, the lead fire investigator is tasked with analyzing all of these interviews. This analysis may dictate re-interviewing some witnesses. Before coming to a conclusion, the lead fire investigator's goal is to use the interview data to test origin and cause hypotheses developed during the investigation.

5-5 Post-Incident Investigation (Non-scene)

Non-scene data" is that which is relevant to some aspect of the fire origin and cause investigation but is not contained within the actual fire scene. Investigators collect "non-scene data" and may use it to help establish the fire or explosion timeline, identify an area of origin, document the growth and spread of the fire, identify suppression efforts which may have affected fire growth and spread, provide context to another piece of data, or to establish evidence of causation (e.g., lightning, intentional human acts). In rare instances, non-scene data may be the most relevant data used to determine an area of origin or a fire cause.

Therefore, fire investigators often analyze and document areas outside of the actual fire scene. They may be attempting to identify evidence, explore vantage points of witnesses or security cameras, examine circumstances leading up to the fire, or to obtain data which helps the investigator understand the overall context of the incident.

“Non-scene data,” as described in this document, is distinctively different from evidence used to establish responsibility, motives, means, and opportunity. The “non-scene data” referred to in this document is only relevant to identifying where the fire started (origin) and the circumstances that brought an ignition source into contact with the first fuel ignited (cause).

Some examples of “non-scene data” include:

- Witness statements (including suspect statements)
- Alarm system activity
- Suppression system activity
- Videos or pictures taken by cameras in or outside the fire scene
- Cellular telephone activity recorded on routers, cell towers found outside of the scene
- Weather reports
- Safety Data Sheets (SDS)
- Burn injuries and toxicological analysis of fire victims
- Recall notifications
- Code enforcement documentation
- Banking, real estate, or insurance files documenting pre-fire physical conditions at the location
- Architectural diagrams or similar documents providing pre-fire building construction data
- Fire modeling
- Field or laboratory testing results
- Physical evidence collected outside of the scene
- Smart meter readings

NFPA 921 and 1033 and "Non-Scene Data"

NFPA 921 [2021] recognizes that data may come from a wide range of sources, stating in Section 14.1

> *"The scientific method requires the collection and analysis of data. This chapter is intended to provide a framework for collecting and analyzing data from sources other than the scene of the incident (non-scene data) using the scientific method. Examining the fire scene or evaluating prior documentation of the fire scene, interviewing witnesses, and conducting research and analysis of information from other sources all provide the fire investigator with additional data to establish origin and cause of a particular fire. Subsequent to the origin and cause determination, non-scene data may be helpful to evaluate responsibility for a fire."*

Also, NFPA 921 section 4.4.3.2 does not specify sources of data but leaves this concept open-ended:

> *"The actual investigation may include different steps and procedures, which will be determined by the purpose of the assignment... A fire or explosion investigation may include all or some of the following tasks: a scene inspection or review of previous scene documentation done by others; scene documentation through photography and diagramming; evidence recognition, documentation, and preservation; witness interviews; review and analysis of the investigations of others; and identification and collection of data from other appropriate sources".*

NFPA 921 has recognized the value of "non-scene data." The document identifies three factors to be used when determining the origin. One of those factors speaks to the coordination of information derived from "non-scene data." Changed in the most recent edition to reflect the consideration of electronic data, Section 18.1.2 states,

> *"Determination of the origin of the fire involves the coordination of information derived from one or more of the following:*
> *(1) Witness Information and/or Electronic Data. The analysis of observations reported by persons who witnessed the fire or were aware of*

> *conditions present at the time of the fire as well as the analysis of electronic data including but not limited to security camera footage, alarm system activation, or other such data recorded in and around the time of the fire event…".*

Also, NFPA 921 Section 18.3.3 lists specific data to consider when determining the origin, much of which would be considered "non-scene data" such as pre-fire conditions, weather history, alarm systems, and witness statements.

NFPA 1033 [2022], does not specifically address "non-scene data," focusing largely on "scene data." Also, a discussion of post-incident investigation job performance requirements includes collecting a variety of data, but the document is addressing issues of responsibility rather than origin and cause with this language.

The Value of "Non-Scene Data"

Depending on the type of fire scene, some or none of this data will be available to investigators. Even if it is available, its value may be negligible, or its value may not be realized until later in the investigation when other additional data is uncovered and analyzed. For example, a security camera across the street from the fire scene may have recorded relevant footage of the fire spread or may have no footage if it was facing the wrong direction. Even if it faced the wrong direction, perhaps it captured data relevant to the circumstances leading to the fire (e.g., lightning strike, vehicle striking a gas meter).

For most fire scenes, there exists "non-scene data" which usually provides critical context to the "scene data." The failure to collect and to consider certain types of "non-scene data" could lead to erroneous conclusions.

Analysis of "Non-Scene Data"

As with data from the fire scene, the analysis of "non-scene data" must be placed within the context of the larger fire investigation. Most of this type of data cannot stand alone — in and of itself, it may mean very little. The data must be used in concert with other data derived from the scene to have a correct interpretation. Also, if a piece of "non-scene data" is inconsistent with other data generated in the case, the investigator is obligated to resolve this inconsistency. "Non-scene data" carries a distinct burden — the investigator must articulate why it is relevant to the origin and cause of the fire, and provide contextual analysis.

Due to the wide variety and sometimes nontraditional nature of "non-scene data," fire investigators may not be trained to identify, collect, or analyze that particular data (e.g., cellular tower data). Fire investigators must be aware of their limitations and be aware enough to call upon other resources when needed.

The most common laboratory analysis conducted in fire investigations is ignitable liquid residue testing using gas chromatography/mass spectrometry. Testing methods used by other forensic science disciplines are also employed. Additional laboratory analyses that may be conducted are listed in Table 5-1.

Table 5-1: Laboratory Analyses

LABORATORY TECHNIQUE	**PURPOSE OF ANALYSIS**
FTIR- Fourier Transform Infrared spectroscopy.	Identify chemical composition
Optical Microscopy	Magnified visual examination
Polarized Light Microscopy	Chemical / mineral composition
Radiography	Visualizations of the internal structure
CT Scan	Visualizations of the internal structure
SEM/EDX-Scanning Electron Microscopy / Energy Dispersive X-ray analysis	Magnified visual examination and elemental composition
Infrared Thermography	Thermal imaging

Evidence Examination Protocols

The purpose of the protocol is to describe the tasks that are anticipated. The protocol should be circulated among the parties, and comments sought. This type of pre-planning often brings out issues that can be resolved before an examination. Parties can be assured that the necessary test equipment will be made available.

A laboratory examination is an investigatory process conducted to find answers. Often, the exam will reveal new data that will logically dictate a change in the protocol.

5-6 Presentations

The culmination of these scene documentation efforts is usually a written report. The content of a written report depends on the agency or party requesting the investigation, the type of expert used, and the scope of their particular analysis. These same factors affect what type of report will be produced, or if any report will be produced at all (reports are almost always required when litigation is joined). Virtually all public sector agencies produce a written origin and cause report designed to detail the fire investigation. There is no standardized format, but at a minimum, the report should list the investigator's opinions and the bases for them.

An origin and cause report generally addresses several factors related to the fire incident: date, location, the identity of victims and occupants, fire department response. The report details the data collected at the scene such as observable fire patterns, physical evidence collected, the state of utilities and appliances, interviews, non-scene data, and what was done to process the scene. This data is then used to test hypotheses developed during the investigation. Ideally, the report will describe the circumstances that brought an ignition source and a first fuel together. Lastly, the report may list the fire cause classification as natural, accidental, incendiary, or undetermined in accordance with NFPA 921.

There is a lack of consistency in retention policies. These policies and laws vary from state to state, allowing investigators in some regions to discard their notes following the production of a formal report. The destruction of such documentation not only violates best practices described in NFPA 921 but may also constitute spoliation of evidence in that other experts are unable to review the data.

ASTM E620-2018, *Standard Practice for Reporting Opinions of Scientific or Technical Experts*, addresses the scope of information to be contained in formal written technical reports (which would include origin and cause reports). The standard addresses report content, including descriptive information, pertinent facts, and opinions and conclusions.
E1020-2013, *Standard Practice for Reporting Incidents that May Involve Criminal or Civil Litigation,* addresses the collection and preservation of information and physical evidence. It also addresses the preparation of a documentation report relative to fire scene investigations. The standard requires the report to contain a detailed chronological narrative, photographs accurately depicting the scene, identification of items or systems involved in the incident, identification of persons involved in the incident, details concerning evidence and any subsequent chain of custody.

5-7 Conclusions

Fire and explosion investigation involves the determination of the origin, the cause, and the development of a fire or explosion. The investigation process is fundamentally based on the scientific method. Once the area of origin is determined, all potential ignition sources are identified within that area. Cause hypotheses are developed which include the ignition source, the first material ignited, and the events that brought the fuel and ignition source together (ignition sequence). The cause hypotheses are tested against the investigation data and the principles of fire science. A cause is determined if one and only one cause hypothesis survives hypothesis testing.

The data collection processes are carried out at the scene, as well as information sources outside the scene. Processes involve evidence identification, collection, protection, documentation, and preservation. Data includes witness information, electronic data, fire damage patterns, physical evidence, arc mapping, fire dynamics analysis, and documentation of the building, its systems, and its contents at the time of the fire. Fire scene processing includes direct observation, photography/videography, debris delayering and examination, sample collection, as well as measurements of the building and the fire damage. Analysis of the data often requires the use of subject matter experts for specific types of analyses (e.g., chemists, engineers).

The data from the investigation is presented and analyzed via the scientific method in the investigation report to produce conclusions about the fire. Fire and explosion investigators are also called upon to provide testimony in depositions, hearings and trial appearances as an expert witness.

REFERENCES

ASTM (2018), *Standard Practice for Reporting Opinions of Scientific or Technical Experts*, ASTM E620-2018
https://www.astm.org/Standards/E620.htm

ASTM (2013), *Standard Practice for Reporting Incidents that May Involve Criminal or Civil Litigation*, ASTM E1020-2013
https://www.astm.org/Standards/E1020.htm

ASTM (2014), *Standard Practice for Collection and Preservation of Information and Physical Items by a Technical Investigator*, ASTM E1188-2014
https://www.astm.org/Standards/E1188.htm

ASTM (2018), *Standard Guide for Physical Evidence Labeling and Related Documentation*, ASTM E1459-2018
https://www.astm.org/Standards/E1459.htm

Carman, S. (2008). Improving the Understanding of Post-Flashover Fire Behavior. *Proceedings of the 3rd International Symposium on Fire Investigations Science and Technology* (ISFI), NAFI, Sarasota, FL.

http://www.carmanfireinvestigations.com/

Tinsley A.T. and Gorbett G.E. (2012), Fire Investigation Origin Determination Survey. *International Symposium on Fire Investigation Science and Technology* (ISFI), pp. 53-68.
https://ssem.eku.edu/sites/ssem.eku.edu/files/files/Gorbett%20-%20FIRE%20INVESTIGATION%20ORIGIN%20DETERMINATION.pdf

Cox, A. (2013). Origin Matrix Analysis: A Systematic Methodology for the Assessment and Interpretation of Compartment Fire Damage. *Fire and Arson Investigator*, International Association of Arson Investigators, Vol. 64, pp. 37-47

Gorbett G, Meacham B, Wood C, Dembsey N (2015). Use of Damage in Fire Investigation: a review of fire patterns analysis, research and future direction. Fire Science Reviews, 4:4,
https://doi.org/10.1186/s40038-015-0008-4

NFPA (2022), *Standard for Professional Qualifications for Fire Investigator*, NFPA 1033, Quincy MA.
http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=1033

NFPA (2021): Guide for Fire and Explosion Investigations, NFPA 921, Quincy, MA.
http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=921

6. IMPROVING METHODS, PRACTICE, AND PERFORMANCE IN FIRE AND EXPLOSION INVESTIGATION

6-1 Introduction

The first five chapters of this strategic plan summarize how fire and explosion investigation is organized and carried out under the current system. There is a need to move forward to strengthen the practice of fire investigations through new practices and procedures, based upon a firm foundation of fire science and implemented through a strengthened operational system that includes strong management systems for fire investigation units (both public and private). This chapter deals with the need for enhancement of the methods, practice, and performance in fire and explosion investigation. Issues related to the needed research (Chapter 7), operation of fire investigation units (Chapter 8) and related education and training of fire and explosion investigators (Chapter 9) are addressed in subsequent chapters.

6-2 Team Approach to Fire and Explosion Investigation

The investigation of most fires begins with the first responders to the fire event. Each firefighter has responsibilities to identify and preserve evidence that potentially relates to the determination of the origin and cause of the fire. Indiscriminate overhaul[19] operations have compromised many investigations. A caricature of the indiscriminate overhaul is the arrival of the fire investigator on the scene to find the contents of a room in a pile outside a window, placed there by first responders. This brings home the fact that a quality investigation requires the expertise and collaboration of all participants. While the archetype of a fire investigator has been a lone

[19] 3.3.135 Overhaul. A firefighting term involving the process of final extinguishment after the main body of the fire has been knocked down. All traces of fire must be extinguished at this time.

wolf who examines a fire scene, a team approach to a fire investigation is more effective and necessary [IAAI 2017].

The need for a team approach has three complementary aspects; 1) safety, 2) the diversity of technical skills required, and 3) the role of collegial interaction in identifying all the available evidence, all the hypotheses that arise from that evidence, and all the hypothesis testing required to reach a proper conclusion. Team interactions may reduce unwarranted assumptions and biases.

Early in the investigation, police and fire department responding units can assist in securing the scene and in scene safety assessment. While police and fire department personnel may have some training in rudimentary fire investigation methods, they consist essentially of not fully trained fire investigators and should only perform fire investigation tasks at the direction of a fully trained fire investigator.

Working safely on the fire scene requires multiple people. Working a scene alone needs to be avoided [NFPA 921 2021 §13.2.1]. The need for additional investigators grows with the size and complexity of the fire scene. See NFPA 921 [2021] Chapter 13 for additional guidance on fire scene investigation safety.

The need for a team approach in complex scenes has long been understood. ATF has had National Response Teams (NRT) in the field since 1978 [ATF 2016]. The NRT's have been activated more than 800 times in the 40-year history of the response teams (about 20 per year) [ATF 2016a]. Each NRT includes Certified Fire Investigators (CFI's), Bomb Technicians, Scientists/ Engineers, Detection K-9's and Handlers, Forensic Auditors, and additional experts as required.

Some State Fire Marshal Offices (SFMOs) also employ a team approach, providing local investigation organizations with investigators with specialized training and experience. In particular, specific technical experts are generally not readily available at the local level and may be more effectively provided by a state agency.

Even at the local level, groups of jurisdictions band together to form response teams made up of investigators from each participating jurisdiction. This provides a means of forming a team with a scope and diversity of skills that no single jurisdiction could muster alone. Working together provides additional opportunities to transfer skills and practices to work toward universal best practice operations in all the jurisdictions. Arson task forces exist as well, their purpose being to conduct long term follow up investigations of intentionally set fires. An ancillary benefit of task forces is that the members get the experience of investigating more fires than they would if they only investigated fires in their home jurisdiction.

Finally, and perhaps most importantly, working as a team in all investigations fosters collaborative investigative work. Team members bring different perspectives to the investigation. All contribute to the identification of evidence, all contribute to the formulation of hypotheses, and all contribute to hypothesis testing. This type of teamwork does not happen automatically. Rather, it requires an investigation culture that encourages both inductive and deductive reasoning by all members of the team.

Investigation teams also provide the opportunity to counteract biases of the individual investigators. The collegial interaction of team members can act to minimize individual biases. At the same time, there is a need to avoid the creation of team biases (groupthink). The diversity of thought and perspective need to be encouraged and nurtured by team management.

- Recommendation*: Fire and explosion investigation units should operate using a team approach. Cooperative investigation task force arrangements with neighboring jurisdictions, with state-level agencies, and with ATF should be organized and supported*.

6-3. Mitigating Bias

Human judgment is subject to many different types of bias. Sometimes the analysis might be affected by unwarranted assumptions and a degree of overconfidence that the investigator does not even recognize. Such cognitive biases are not the result of character flaws; instead, they are common features of decision making. A common cognitive bias is the tendency for conclusions to be affected by how a question is framed or how data are presented. Other cognitive biases may be traced to common imperfections in our reasoning ability.

Bias is well known in science, and significant effort has been devoted to understanding and mitigating bias. The goal is to make scientific investigations as objective as possible, so the results do not depend on the investigator. Avoiding, or mitigating, bias is an important task.

NFPA 921 discusses two sources of contextual bias: expectation and confirmation. Proper application of the scientific method as well as critical review of an investigator's conclusions are important tools in mitigating potential bias.

Expectation bias arises when investigators reach premature conclusions. By not collecting and examining all of the relevant data, or by relying on irrelevant data, an investigator can form invalid conclusions. The tendency then is to disregard new or inconsistent data by "explaining it away." Avoiding expectation bias first requires the investigator to identify all the available data. The investigator then needs to collect all that data and analyze all the data before developing and testing his hypothesis. In other words, properly following the scientific method.

Confirmation bias occurs when an investigator lapses into seeking to prove rather than refute a hypothesis. As the scientific method dictates, testing of the hypothesis should be designed to disprove that hypothesis. This testing needs to be sufficiently rigorous to discriminate among competing hypotheses.

Motivational bias is a discrepancy, usually conscious, motivated by one's personal situation. Such biases can be introduced by organizational objectives and culture, or by stakeholder expectations. Fire investigators often work directly for organizations or clients that may have biases for certain outcomes. There is general acceptance that forensic experts, including fire investigators, should be shielded from influence from stakeholder expectations.

In civil proceedings, these sources for potential bias are offset by extensive disclosure requirements and depositions. In civil proceedings, experts from both sides are required to reveal their opinions and the underlying analysis so that judges can perform their gatekeeper duties prior to trial.

In criminal proceedings, the scientific experts, which includes the fire investigators, have much less rigid disclosure requirements which make it more difficult for judges to perform their gatekeeper duties. Experts for the prosecution are typically required to provide reports, but in some jurisdictions, are not required to provide them until after they testify on direct examination. Unfortunately, there is sometimes insufficient detail in the prosecution expert reports to explain how the opinion was arrived at, which limits the defense's ability to challenge the result. Experts for the defense often provide no report or only a brief summary, which provides no opportunity to challenge the bases of their opinions. Even when reports are provided to the opposing side for review, it is common practice for experts to opine during trial about things that were not mentioned in their reports. This is particularly common when attorneys fail to conduct due diligence and judges fail to perform their gatekeeping function.

To guard against presumptions and mitigate bias, there is a need to consider only data that are relevant to the current task (see NCFS [2016] concerning the need to limit data considered to that which is relevant to the current task). If the task is the determination of origin and cause of the fire, then relevant data includes information about the fire scene and the actions that occurred at the fire scene. The data may relate to the fire scene and actions before the fire, during the fire, and after the fire. The data may be physical or may be an action or observation. The relevance relates to the value of the data in determining where the fire originated, how it was caused, or how the fire developed.

Task-irrelevant data, as it pertains to origin and cause determination, often relate to motives. Financial, criminal history, social relationship stress, evasive, or deceptive behavior information are not relevant to the determination of the origin or cause of a fire. Table 6-1 provides examples of data that are relevant to origin and cause determination and examples of data sources of potentially task irrelevant data for origin and cause determination .

Table 6-2: Task relevant data and sources of potentially irrelevant data for origin and cause determination. Irrelevant data are generally related to motives.

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

Security, detection, and alarm systems Overpressure damage	

It is sound practice for the fire investigator to initially only consider data needed for an origin and cause determination. Shielding the fire investigator from information not directly relevant to the origin and cause of the fire has been suggested as one way that this can be accomplished [Lentini 2008]. When resources exist, other investigators should be assigned to develop "non-scene" data, including interviewing witnesses. Witness information relevant to the fire can then be presented to the fire investigator. When fire investigators are working alone, they need to use care in the sequence in which data is collected and analyzed. To the extent possible, the fire investigator should collect data directly related to the origin and cause first.

Physical evidence, including samples for laboratory analysis, should be marked with information to identify the sample unambiguously and with the information the scientist requires to carry out their forensic analysis. Evidence markings should not include extraneous information that a forensic scientist does not need to perform the analysis. For example, a laboratory chemist doing ignitable liquid analyses does not need to know why a sample was taken for analysis. Whether the sample was taken due to a canine alert or some pattern evidence observed by the investigator are wholly irrelevant data for the chemist.[20] Conversely, knowledge of the substrate and the existence of a comparison sample is relevant.

There are methods available to allow the collection of all data while screening the data for relevance before providing it to the fire investigator(s) determining origin and cause [Lentini 2008, Lentini 2015]. Because most irrelevant data arises out of non-scene data, a portion of the

[20] On the other hand, someone should be responsible for comparing canine alerts to laboratory confirmations and keeping that data available so canine performance on actual fire scenes can be assessed.

job of an *investigation manager*[21] is to manage the flow of information. During this process, data not relevant to the origin, cause, and development of the fire can be screened from the investigator(s) making these determinations. In other circumstances, the method of sequential unmasking of data can be formally or informally implemented. A simple, informal application of sequential unmasking is conducting the fire scene examination before police interviews with neighbors are shared with the fire investigator. A downside of these methods is that they require additional personnel and resources during the active portions of the investigation that are not always available in today's fire investigation units.

Technical reviews of the work product should be performed. These reviews are a way to identify other potential hypotheses and further test the hypotheses. Technical reviews can also identify and mitigate bias [NFPA 921, §4.6.2]. While it may not be possible to shield the fire investigator from all information that is irrelevant for the origin and cause determination, it is possible to provide the technical reviewer with only the relevant data and therefore allow the reviewer to evaluate if the same determination would have been achieved with only relevant information.

- Recommendation*: Fire and explosion investigation units should implement practices to minimize potential bias by using such processes as rigorous adherence to the scientific method, a technical review process, and processes to limit the exposure of investigators to biasing information.*

6-4 Reporting Results of the Fire and Explosion Investigation

> *Writing is thinking. To write well is to think clearly.*
> *That's why it's so hard. David McCullough*

The report in a fire investigation is much more than documentation; it is a part of the analytical process. As historian David McCullough has noted,

[21] Investigation manager or a case manager –primary role of limiting the task irrelevant data provided to the fire investigator, whose primary role is origin and cause determination.

"Writing is thinking." Writing is a discipline that forces you to examine your assumptions and challenge your reasoning. Even the anticipation of writing the report has a beneficial effect on data collection, hypothesis formation, and hypothesis testing.

For many, writing the report is onerous and the least desirable aspect of the fire investigation. The temptation is to draft a short narrative report instead of a comprehensive report. Investigators would do well to remember a widely used saying, "If you didn't write it, you didn't do it." A short narrative report may indicate that an investigation was a cursory affair.

The existing guidance on writing fire investigation reports is modest. NFPA 921 has Section 16.5 which runs about half a page. There is more general guidance for forensic reports such as ASTM E620, *Standard Practice for Reporting Opinions of Scientific or Technical Experts* [2018]. Formats of reports vary by the investigation unit and by the intended audience. Fortunately, deciding on the structure and content of a fire investigation report is a fairly straightforward exercise.

A fire investigation report needs to begin with simple descriptive material about the fire location and date, along with a statement of the purpose of the investigation. Most often this is to determine the origin and cause of the fire, but it may have the goal of assessing how and why the fire spread subsequently, or how the fire interacted with building systems to cause the resultant damage.

Early in the report, there is a need to describe the property to provide information about the site. The construction type, the occupancy, and basic contents of the building are required. Site plans, floor plans, and pre-fire photographs are all helpful. Building contents, layout, and building systems are described. The degree of detail required varies with the fire situation and building. Documenting a security system that was not in use at the time or details of a part of the building not involved in the fire and smoke movement may not be required. The fire incident will dictate where the most detail is required.

The report should include a section on the circumstances surrounding the fire, including when and how the fire was discovered, and information about the fire suppression and rescue operations. These will generally provide some important timeline data along with important witness information about the fire. Most often, information that results from detailed interviews is not included in this early descriptive information. It generally portrays the knowledge of the fire incident before the investigation begins.

The report needs to include relevant data collected during the investigation. This includes data collected at the fire scene, data from interviews, as well as other sources of data such as fire department or building department documentation. It is common to summarize data elements in the report and provide the full data documentation in an accompanying file or appendix to the report. All relevant data should be included in the report, both data that is consistent and inconsistent with an investigator's origin and cause hypothesis. Discarding or ignoring inconsistent data can lead to faulty conclusions. Data collection should normally be separated from data analysis in the report.

The origin determination analysis needs to be described in detail. All origin hypotheses that arise out of the data need to be articulated. Each origin hypothesis needs to be subjected to rigorous testing fully described in the report. The results of the testing that led to the ultimate origin determination need to be described.

Once the area of origin is established, all potential ignition sources need to be considered and used to develop cause hypotheses. In rooms that have been fully involved for more than a few minutes, every potential ignition source within the room should be hypothesized and tested as a cause. All cause hypotheses need to be described in the report. The testing of each of these hypotheses needs to be addressed in the report. The report needs to identify the hypotheses that survive the testing process and report the findings concerning the fire cause.

The reasoning associated with the origin and the cause hypothesis testing should be fully described. Information sources in the forensic and fire science literature used in hypothesis testing should be cited in the report and included in a reference list. Sections of NFPA 921 used in the investigation should be directly cited in the report.

As the above discussion demonstrates, writing an origin and cause report is an extensive process involving documentation, analytical thinking, and complete disclosure. All elements of the scientific method as employed in the investigation are fully described and discussed. The goal is to provide sufficient detail that readers can reproduce for themselves the reasoning from data to conclusions. The reader should be able to assess the level of significance of each piece of data, to independently test each hypothesis, and to reach independent conclusions.

There are normally additional materials cited by the origin and cause report that may appear as appendices or independent cited documents. These include photos and accompanying photo logs, laboratory reports, diagrams, sketches, physical evidence, laboratory or field notes, and modeling files. In essence, the entirety of the investigative file should be included in the report or accompanying cited files or documents.

An origin and cause report is much like the investigation itself in that it is often a team effort. All the contributors to the report should be identified. It is common for individual contributors to write independent reports covering their portion of the investigation. When this approach is taken, the main report needs to summarize the component reports and cite the component reports for the complete description of the work.

As with any work product, an origin and cause report should be technically and administratively reviewed according to the policies and procedures of the fire and explosion investigation unit. The goal of these reviews is to assure completeness, clarity, and technical quality. Organization and operation of fire investigation units to support quality investigations is considered in detail in Chapter 8.

In the end, it is the responsibility of all stakeholders (investigators, managers, lawyers, judges, insurance companies) to prepare and cause to be prepared complete and comprehensive fire and explosion investigation reports reflecting the best fire science, analyzed using the scientific method. As long as the industry accepts inferior fire and explosion investigation reports, the promise of modern fire and explosion investigation science and technology will not be realized.

There are challenges in the criminal justice system that impede accountability for the quality of fire and explosion investigation reports used in legal proceedings such as:

- inadequate counsel for defendants,
- inadequate funding for experts,
- judges not requiring reliability hearings to evaluate the expertise and methodology of the experts testifying in court,
- judges being ill-prepared to assess the adequacy of a fire and explosion investigation report, and as a result not embracing their "gatekeeping" function for science in the courtroom, and
- prosecutors and defense attorneys not being familiar with fire investigation best practices.

- Recommendation: *Fire and explosion investigation reports should include all data collected, all hypotheses formulated, details of the testing process for each hypothesis, and the conclusions of the investigation.*
- Recommendation – *In a case where an incendiary fire cause has been alleged, the origin and cause of the fire should be thoroughly explored through discovery or evidentiary hearings*
- Recommendation – *Judges and lawyers should be educated and trained on fire investigation (see also the NCFS [2015] recommendation, Recommendation to the Attorney General Forensic Science Curriculum Development)*
- Recommendation: *All stakeholders (investigators, managers, lawyers, judges, insurance companies) must take responsibility for requiring complete and comprehensive fire and explosion investigation reports.*

REFERENCES

ATF (2016), Fact Sheet - National and International Response Team, https://www.atf.gov/resource-center/fact-sheet/fact-sheet-national-and-international-response-team

ATF (2016a), ATF's National Response Team; How ATF Assists State/Local Law Enforcement and Fire Agencies, https://www.atf.gov/resource-center/fact-sheet/fact-sheet-national-and-international-response-team

Lentini, J (2008) Toward a More Scientific Determination: Minimizing Expectation Bias in Fire Investigations. *International Symposium on Fire Investigation*, Investigations Institute. https://drive.google.com/drive/folders/1d_V2v8q8fkWAmsxCD3icf6Qi-LYziR47

Lentini, J (2015) Contextual Bias in Fire Investigations: Scientific vs Investigative Data, *The Brief*, American Bar Association, Tort Trial and Insurance Practice Section, 44 (3). https://storage.googleapis.com/production-constantcontact-v1-0-7/507/175507/IaE9rCjE/8471dae61f1346e8b11abd83c03edb2e?fileName=2015%20Contextual%20Bias%20in%20Fire%20Investigations%20Scientific%20Investigative%20Data.pdf

Gorbett, G., Meacham, B., Wood, C., Dembsey, N. (2017). "Structure and Evaluation of the Process for Origin Determination in Compartment Fires." *Fire Technology*, January 2017, Volume 53, Issue 1, pp 301–327 https://link.springer.com/article/10.1007/s10694-015-0553-3

IAAI (2017), The Team Concept, Duties and Responsibilities, Interfire Online. http://www.interfire.org/res_file/team.asp

National Commission on Forensic Science (2017), Work Products of the FCFS, https://www.justice.gov/archives/ncfs/work-products-adopted-commission

NFPA (2017): *Guide for Fire and Explosion Investigations*, NFPA 921, Quincy, MA.
http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=921

7. RESEARCH NEEDS IN FIRE AND EXPLOSION INVESTIGATION

7-1 The Current State

Fire investigation, like many other forensic science disciplines, suffers from an inadequate research base. Much of the research conducted into fire phenomena has developed over the last fifty years and was primarily aimed at understanding factors related to fuels and the development of fires in compartments. This research was driven by a desire to improve fire safety rather than being focused on determining the origin and cause of fires. Much of the study related to fire investigation has been conducted on a more or less *ad hoc* basis to understand issues related to a particular fire rather than to understand the broader nature of fire investigation methodologies.

As discussed in Chapter 4, fire investigation is generally thought of as a two-step process. The first step is to determine the origin (where the fire started), and the second step is to determine the cause (how and why the fire started). Unless there is a reliable human witness or electronic monitor, origin determination is based largely upon the investigator's interpretation of the effects of the fire and the patterns those effects create. Cause determination involves the analysis of fuels and the interaction of those fuels with heat sources.

The determination of fire origin is based largely on the analysis of the damage caused by the fire. At times, fire investigators interpret the patterns left by the fire without a rigorous scientific understanding of the nature of fire patterns as well as when and how those patterns were created. The science underpinning our understanding of the nature of fuels and the reaction of fuels to heat (fire effect) is more fully developed.

Various procedures, protocols, and methods have been developed and can be used by fire investigators to assist in reaching conclusions about origin and cause. Within the fire investigation discipline, there is currently little rigorous scientific study establishing the strengths and limitations of various methods and procedures. There is also little information to identify sources of bias and the impact of variations in these processes. Existing guidance in NFPA 921 does not fully address the uncertainty, repeatability, and limitations of the current methodologies.

Between 2007 and 2017, The National Institute of Justice (NIJ) had awarded 19 grants for research in the area of "Arson." Half of these grants were specifically related to analyzing ignitable liquid residue, a laboratory endeavor. The remaining focused on discrete elements related to fire investigation.

A broader focus on those key datasets most often relied upon by fire investigators is needed in research. The results of that research need to be translated into practical tools that can be employed by investigators at fire scenes.

7-2 Establishing a Research Agenda

The National Commission on Forensic Science [NCFS 2017] has provided a number of recommendations for the need for further scientific inquiry and research in support of forensic science. In order to guide research in fire and explosion investigation, there is a need to establish a research agenda in the field that can assist funding agencies in setting priorities and motivate investigators to examine the most critical needs of the profession.

Two broad areas of research needs have been identified. One deals with the validation of origin and cause determination protocols. The need here is for comprehensive, statistically sound assessments of current methodologies and the identification of new methodologies. The other area involves reducing the potential for bias in fire and explosion investigations. The need here is for methods and protocols to reduce bias associated with data collected by a fire investigator that is irrelevant to the determination of origin and cause.

Regarding origin determination, NFPA 921 identifies various techniques for analyzing and interpreting damage (fire effects and patterns). These include heat and flame vector analysis, depth of char analysis, depth of calcination surveys, electric arc surveys, and origin matrix analysis. Vector analysis and depth of char were discussed in the first edition of NFPA 921 in 1992. Arc surveys were introduced in the 2001 edition of the document and origin matrix analysis first appeared in the 2017 edition. Each of these techniques has been the subject of varying degrees of study, and the results have been published in the fire investigation literature. There is considerable variability in the techniques used in these analyses. None of these techniques has been fully validated. Changes in manufacturing processes (e.g., lightweight gypsum wallboard) may impact the validity of depth of calcination surveys. The wider use of arc fault circuit interrupters will likely impact arc surveys. Ongoing research is needed to assure that methods remain viable as technologies evolve.

Fire investigators collect data that may be found to be irrelevant to the origin and cause determination. This data may bias an investigator's origin and cause conclusions. Research is needed on methods and procedures to manage this information and to limit its impact.

- Recommendation*: The Research Agenda developed below should be adopted by research funding agencies and should be carried out over the next several years.*

The Research Agenda Items outlined below are purposely broad in identifying general categories of needed research. It is expected that each recommendation will result in numerous discrete research projects.

7-2.1 Origin Determination

Concerning origin determination, NFPA 921 identifies three general categories of information from which data can be gathered and analyzed to form the basis for origin conclusions. These are fire patterns, including arc mapping, witnesses and electronic information, and fire dynamics analysis.

Research is needed in each of these areas to enhance the science of fire investigation.

Information on the properties of fuels, the characteristics of heat sources, and the interaction of the two is important in the determination of fire cause. Much of this information comes from fundamental fire dynamics research.

Fire Patterns

Fire investigators almost always base their origin determination on the interpretation and analysis of fire patterns. For the conclusions to be reliable, the investigator must have an understanding, based on fire dynamics, of *when* during the fire, those patterns were created. The investigator must also understand *how* those patterns were created – a fire plume, a hot gas layer, and the effects of ventilation, flashover, and suppression.

The study of mechanisms that produce fire effects and patterns is one area of research needed. Over eighty years of research related to fire patterns have been compiled and provided in a recent publication [Gorbett et al. 2015]. Additional work on the effects of ventilation on pattern production with varying room and ventilation opening configurations are important to validating pattern analysis methods.

In most room fires, the patterns of interest are created on surfaces — floors, walls, contents, and ceilings. Changes in materials of these surfaces affect pattern creation. Research is needed to understand further the effect that material properties have on the nature of the pattern creation.

Post-fire, many patterns exist within a building and the room of origin. It is the accumulation of patterns and the relationship of patterns, rather than a single pattern, that need to be analyzed. There has been little research on methodologies and procedures to assist the fire investigator with assigning meaning to a broad array of patterns.

Research Agenda Item #1 *- Develop a coordinated research program to analyze the effects that ventilation has on the creation and obscuration of fire patterns related to the origin of a fire.*

This is of high priority. The impact on fire investigations is significant.

Doors, windows, and other openings in a compartment introduce air, allow the escape of heat and thus affect temperatures and flow patterns. Temperature and flow, in turn, create and destroy patterns on the compartment surfaces. Given the influence of these factors, a pattern that is observed post-fire may or may not be related to the origin. Without a solid understanding of these effects, fire investigators may misinterpret these patterns, thus making an erroneous conclusion about the origin of a fire.

The ATF has published information on a procedure called "Origin Matrix Analysis" that was introduced in 2013 and incorporated into the 2017 edition of NFPA 921. Much more work is needed in compartments of various sizes with a combination of vents to refine this technique further and to translate the research into information that can be applied by the fire investigator.

A prototype process called the "Process for Origin Determination" was published [Gorbett et al. 2017]. This process evaluated fire damage in the context of what compartment fire dynamics caused the damage. To date, this is the only procedure to have published findings as to its effectiveness at increasing reliability and validity of its use with practitioners.

Research Agenda Item #2 *–Develop a coordinated research program to analyze the effect that material properties have on the nature of the pattern creation.*

This is of medium priority. The impact on the conclusions made by fire investigators could be significant as changes are made in the substrate and finish materials.

Almost all of the guidance on wall and ceiling patterns in NFPA 921 is based on those surfaces being unpainted gypsum wallboard available at the time of the testing. Fire investigators must understand that their analysis and interpretation of patterns may change as the material on which those patterns manifest themselves change. The effects that are created on surfaces other than this material are largely unknown. Research is particularly needed on how residential construction methods and practices have changed and the attendant impact on using fire patterns to determine fire origin.

Research Agenda Item #3 – *Require that fire investigation be a component in future public funding of compartment fire research.*

Research Agenda Item #4 – *Encourage fire research organizations currently conducting compartment fire research to include fire investigation components in those fire tests.*

This is of high priority. The impact could be significant.

Over the last several years a series of full-scale tests in laboratory constructed compartments and formerly occupied buildings has been conducted. Additional testing is planned. The ability to use buildings for testing is of great value because such testing presents the most realistic conditions possible. Testing programs such as these should be expanded so that as data is gathered and analyzed. The research can benefit the fire investigation community. The proposed research would not interfere with planned research goals as the data gathering would be conducted after the fire test.

Public funding for these programs should require that fire investigation be a component of compartment fire research.

Research Agenda Item #5 – *Investigate the impact of room size on the generation of patterns and the validity of using those patterns for origin determination.*

This is of medium priority. The impact is significant if the current trend in residential housing construction continues.

In the last twenty years or so, the trend in single-family home construction has been to move away from small rooms low in height to larger open areas with high ceilings. A home today may have the living area on the ground floor constructed as one large open area without walls separating functional spaces. Sleeping areas may be large suites rather than individual bedrooms and bathrooms. Most of the research on patterns has been conducted in "typical" size rooms; for example, ten feet by twelve feet by eight feet in height. Research is needed in larger spaces with modern furnishings to identify this impact on patterns.

Research Agenda Item #6 – Develop protocols, techniques, and instrumentation to conduct measurements to quantify fire patterns reliably. Evaluate the reliability and validity of these techniques as measurable tools for pattern analysis in the process of origin determination.

This is of high priority. The impact depends upon the usefulness of the techniques.

Most fire investigators currently rely on subjective analysis of fire patterns. Measurable techniques for analyzing fire patterns would improve the reliability and validity of using this data to determine fire origin.

NFPA 921 has information on calcination and char depth measurements as a tool to assist in origin determination. Many consider these techniques to be imprecise and of questionable value. They are not employed by most fire investigators because of the time required and because of a lack of perceived usefulness. Additionally, there is little data on how differences in the material composition of construction components such as gypsum wallboard may impact these techniques.

Results of this research need to be reported in such a way that it is practical and usable by the fire investigator. The protocols and techniques developed need to be in a form that supports the analysis of fire growth in the compartment.

Arc Mapping

Locating and interpreting electric arc damage on components of building electrical systems has been recognized as an origin determination tool for over twenty years. It has been included in NFPA 921 since 2001. The theory and technique of this method are based upon the wiring methods and components that were used in the past. As new techniques and components are used in building electrical systems, the creation of arc damage from a fire and the implications of that damage to origin determination need to be reevaluated.

Research Agenda Item #7 – Develop a coordinated research program to analyze the effects that electrical equipment such as ground-fault circuit interrupters (GFCI) and arc-fault circuit (AFCI) interrupters have on the process of arc-mapping.

This is of medium priority. The impact is significant.

Arguably, the process of identifying and mapping areas of electrical activity (arcing) on conductors and using that information as data in origin determination is an effect (and thus a pattern) of a fire. Arc mapping has been identified as important origin data since its inclusion in the 2001 edition of NFPA 921. Research to date has shown that arc mapping is a valid tool in origin determination. There has been little research into the impact that GFCIs and AFCIs have on the creation of arcs and the resultant damage to copper conductors. Fire investigators need to understand the importance of considering such impacts on the analysis of arc damage data.

Witness Information and Electronic Data

Research Agenda Item #8 *– Develop protocols or techniques for collecting, extracting, and analyzing data from the variety of witnesses from a fire scene (e.g., eyewitnesses, first responders, and owners).*

Fire investigators are well informed on the need to develop information from those who first observe the fire and from those who subsequently arrive to extinguish the fire. Fire investigators also are aware of the importance of gathering information from those familiar with the pre-fire conditions like the layout of furnishings and appliances in the room of origin. Training is common on how to conduct such interviews but uncommon on how to accurately use the information for origin determination. There is no specific process outlined within NFPA 921 for the use of eyewitness information.

This is of medium priority. The impact is significant.

Most also recognize the importance of information from security cameras and alarm systems.

Data from "internet-of-things" devices that might be stored within the device at the fire scene, at some remote storage location, or in the cloud can provide significant insight into fire origin and spread.

Research Agenda Item #9 *– Develop awareness of methods for collecting, extracting, and analyzing data from the variety of electronic sources now finding their way into residential and commercial buildings.*

This is of medium priority. Currently, the significance is low but, as these devices become more commonplace, the significance will likely increase.

Fire investigators need to understand the type of information that might be available and how to access that information. Given the potential evidentiary value, investigators need to understand the issue of protection and preservation of this information. Aside from a brief mention, there is no information on this topic currently in NFPA 921.

Fire Dynamics

The performance of fuels on the ignition and the subsequent growth and spread of the fire impacts an investigator's determination of both fire origin and fire cause. Critical fuel characteristics, such as ignition temperature, are not well understood and not appropriately applied by many fire investigators. Mechanisms of ignition are misinterpreted because of a lack of understanding of heat transfer. Most of this is well documented in the fire science literature and well understood by fire scientists.

Research Agenda Item #10 *– Develop practical tools that can be used by the fire investigator to evaluate fuel characteristics and the performance of fuels under fire* *conditions in support of understanding fire growth as it relates to the determination of origin.*

This is of medium priority. The impact is significant.

The primary characteristic of fuels used by fire investigators today is ignition temperature. These temperatures are published for many fuels in a variety of sources. Often the temperature is reported as a discrete number. In evaluating fire cause, fire investigators often misapply the concept of ignition temperature when evaluating the viability of a fuel given a known heat source. Ignition temperature, however, is less important when evaluating ignition source or fuel competency than critical heat flux, the minimum heat flux that can cause ignition. This is a concept with which many investigators need to become more conversant. Heat release rates of common materials and fuel packages are required to support fire growth analyses. Fuel characteristics need to be cataloged and reported in a way that can be used validly by fire investigators.

7-2.2 Cause Determination

New technologies and products coming to market have always presented new challenges to the fire investigation community in identifying the cause of fires. In recent years, one of the most widely reported issues with a new product causing fires is lithium-ion batteries. As this battery technology advanced and became more viable, these types of batteries found their way into a wide variety of products. Fire incidents were reported to the CPSC, and several products have been recalled.

***Research Agenda Item #11** – Require manufacturers reporting recalls and the CPSC to make available data that is developed in determining a product recall that identifies the failure mechanism.*

This is of high priority. The impact is significant.

Information reported to the public by CPSC is generally not specific as to the mechanism of failure. Many fire investigators assume that just because a product is recalled, it is the likely ignition source if found in the area of origin in a particular fire. By providing detail on the failure mechanisms and circumstances required for a fire to occur, the quality and validity of cause determination would be enhanced. By improving the quality and validity of cause determinations, the fire investigation community could provide enhanced feedback to CPSC and manufacturers.

7-3 Getting Research into Practice

Publicly funded fire investigation research is critical to get that research into practice. Many times, fire investigation research is conducted privately to support a particular investigation with pending litigation. This research is seldom published. Most fire investigators are practitioners rather than researchers. State and local public agencies or small private companies most often do not have the resources to conduct testing. Research grants targeting fire investigation by government entities such as NIJ and fire investigation research projects undertaken by government fire research laboratories at NIST and ATF would substantially contribute to the discipline.

The results of research should be published in a forum available to fire investigators in a form useful to practitioners. The goal should be getting the research results into practice by communicating to the fire investigation community via trade publications and educational seminars. Consideration should be given to the fact that NFPA 921 is updated on a three- or four-year cycle. Getting information distributed to the fire investigation community via a new edition of NFPA 921 is not necessarily timely but publication in NFPA 921 gives new techniques a strong endorsement.

Research Agenda Item #12 – *Create an easily accessible repository for research on fire investigation.*

This is of high priority. The impact is significant.

The Technical Committee charged with writing NFPA 921 works to include references to research in that document. Since the document is updated on a three- or four-year cycle, references to new research are likely not included in that document. Federally funded research is reported in a variety of ways and can be found (many times not easily) in various online and printed sources. There should be a single online repository easily accessible to fire investigators where this research can be found.

Research Agenda Item #13 – *Develop a mechanism for disseminating research conducted by the ATF Fire Research Laboratory.*

This is of high priority. The impact is significant.

The ATF Fire Research Laboratory is the federal facility charged with conducting research specifically related to the investigation of fires. This research is not often disseminated. A mechanism needs to be developed so that this research can be disseminated in a timely fashion to the broader fire investigation community.

Research Agenda Item #14 – *Require that federally funded research into fire phenomena that involves full-scale fire testing include a component to document post-fire conditions.*

This is of high priority. The impact is significant.

Several federal agencies conduct or fund full-scale fire research for various purposes other than fire investigations. Many times, the post-test conditions are not documented or evaluated. This is lost information from a test that is costly to conduct. Requiring that the post-fire conditions, such as patterns, be documented and disseminated for use by the fire investigation community will help to make the most of such tests.

Research Agenda Item #15 – *Develop techniques to limit the exposure of fire investigators to potentially biasing information that can be practically applied during a fire investigation.*

Research Agenda Item #16 – *Develop techniques to identify and manage bias in the development of conclusion by fire investigators.*

These are of high priority. The impact is significant.

It is sound practice for the fire investigator to initially only consider data needed for an origin and cause determination. Shielding the fire investigator from information not directly relevant to the origin and cause of the fire has been suggested as one way that this can be accomplished. The practicality of various shielding techniques has been debated with the fire investigation community.

Research is needed to develop processes and application techniques for fire investigators to use in identifying and collecting data solely relevant to origin and cause determinations.

Research is also needed in the development of procedures to be used by fire investigation units to use in identifying and controlling bias before origin and cause conclusions are finalized.

7-4 Conclusions

The research needs of the fire investigation community are constantly evolving as the nature of the structures within which fires occur changes and as the nature of the materials that burn changes. Funding for research in the area of fire investigation is extremely limited. Research funding needs to be increased and sustained to support these investigation needs. Because of the diverse interests involved in fire investigation, there needs to be a mechanism to evaluate, prioritize, and coordinate research. It is important that a group of practitioners representing a variety of interests as represented by this OSAC Subcommittee have regular input on an ongoing basis. This Subcommittee desires that those applying for fire investigation research grants look to these recommendations for areas of need. It is also the desire of this Subcommittee that those funding such research give priority to proposals in these areas.

Research Agenda

#1 - Develop a coordinated research program to analyze the effects that ventilation has on the creation and obscuration of fire patterns related to the origin of a fire.

#2 –Develop a coordinated research program to analyze the effect that material properties have on the nature of the pattern creation.

#3 – Require that fire investigation be a component in future public funding of compartment fire research.

#4 – Encourage fire research organizations currently conducting compartment fire research to include fire investigation components in those fire tests.

#5 – Investigate the impact of room size on the generation of patterns and the validity of using those patterns for origin determination.

#6 – Develop protocols, techniques, and instrumentation to conduct measurements to quantify fire patterns reliably. Evaluate the reliability and validity of these techniques as measurable tools for pattern analysis in the process of origin determination.

#7 – Develop a coordinated research program to analyze the effects that electrical equipment such as ground-fault circuit interrupters (GFCI) and arc-fault circuit (AFCI) interrupters have on the process of arc-mapping.

#8 – Develop protocols or techniques for collecting, extracting, and analyzing data from the variety of witnesses from a fire scene (e.g., eyewitnesses, first responders, and owners).

#9 – Develop awareness of methods for collecting, extracting, and analyzing data from the variety of electronic sources now finding their way into residential and commercial buildings.

#10 – Develop practical tools that can be used by the fire investigator to evaluate fuel characteristics and the performance of fuels under fire conditions in support of understanding fire growth as it relates to the determination of origin.

#11 – Require manufacturers reporting recalls and the CPSC to make available data that is developed in determining a product recall that identifies the failure mechanism.

#12 – Create an easily accessible repository for research on fire investigation.

#13 – Develop a mechanism for disseminating research conducted by the ATF Fire Research Laboratory.

#14 – Require that federally funded research into fire phenomena that involves full-scale fire testing include a component to document post-fire conditions.

#15 – Develop techniques to limit the exposure of fire investigators to potentially biasing information that can be practically applied during a field investigation.

#16 – Develop techniques to identify and manage bias in the development of conclusion by fire investigators.

REFERENCES

Gorbett, G., Meacham, B., Wood, C., Dembsey, N. (2017). "Structure and Evaluation of the Process for Origin Determination in Compartment Fires." *Fire Technology*, January 2017, 53 (1), pp 301–327 https://doi.org/10.1007/s10694-015-0553-3

National Commission on Forensic Science (2017), Work Products of the FCFS, https://www.justice.gov/archives/ncfs/work-products-adopted-commission

NFPA (2021): Guide for Fire and Explosion Investigations, NFPA 921, Quincy, MA. http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=921

8. STRENGTHENING OVERSIGHT OF FIRE AND EXPLOSION INVESTIGATION PRACTICES

8-1 Certification of the Individual

As outlined in Chapter 2, many professions employ certifications that affirm that an individual has gone through a defined process of instruction, study, and testing, has agreed to a Code of Ethics and continuing professional development. The OSAC Fire and Explosion Investigation Subcommittee agrees with the National Commission on Forensic Science's position that fire investigators, as forensic science practitioners, should become certified [NCFS 2016]. Any valid certification program requires the fire investigator to be re-certified periodically by maintaining a minimum number of continuing education hours.

The challenge is that simply being certified is not sufficient. There are numerous cases of certified fire investigators who deviate significantly and without justification from NFPA 921 and NFPA 1033 [Lentini 2017]. Fire investigators must consistently prove that they adhere to the current science in the profession, and the criminal justice system needs to require all participants in the fire investigation to comply with national best practices.

- Recommendation: *Certify fire investigators by a third party and obtain other credentials that ultimately enhance their knowledge.*

Competency Testing vs. Proficiency Testing

Do fire investigators need competency testing, proficiency testing, or both? "A competency model is the traditional way to identify what needs to be included in a typical training program. A competency model breaks training elements down into three parts: Knowledge, Skills, and Abilities (KSAs). When building a competency model, one compiles a long list of training elements to include in training. This requires peer groups of professionals to decide on the importance of and frequency of each KSA. The downside of this testing approach is that it often misses how competencies work together in different combinations to produce the desired result. A proficiency model, on the other hand, provides a completely different point of view. Proficiency is both a measure of performance and a set of observable behaviors that describe what a proficient investigator produces and how the investigator must work to achieve those results. Proficiency is a snapshot of what success looks like on the job. With a competency model, one can master all the competencies and not produce the desired results on the job. In other words, all the pieces do not add up to the whole. With a proficiency definition, the result is completely defined, and training does not end until the individual becomes proficient. The result is important rather than all the pieces and parts." [Atwert, 2011].

Competency testing typically occurs for fire investigators when certifications are acquired. Proficiency testing is not common for most fire investigators. Fire investigators are certainly expected to follow the practices outlined in NFPA 921 and meet the qualification requirements of NFPA 1033. There are numerous training courses that fire investigators can take to acquire the knowledge of the sixteen topics required by NFPA 1033. The difficulty, as stated above, is how all the competencies work together to produce a fire investigator who performs in accordance with these two NFPA documents in their daily activities. Competency testing shows that the investigator at a point in time passed the exam and completed the training course. That is important, but the training and evaluation cannot stop there.

A proficiency model is an environment where the fire investigator is evaluated through their reports, trial or deposition performance, mock reliability hearings, reviews of investigations by independent third parties, and other processes that measure cumulative proficiency. Proficiency testing evaluates how the investigator utilized all their education, certifications, and training in the performance of their job as it relates to professional best practices. Proficiency evaluations of performance are not a regular function within most fire investigation organizations. This type of evaluation needs to be as common as competency testing to encourage fire investigators in their professional development.

- Recommendation: *Require competency and proficiency testing for fire investigators both in their training and the continued monitoring of their work product.*

8-2 Accreditation of Certification Bodies

For certifications to have validity, they must be challenging to attain, and the entity that confers them must be reputable as well. The National Commission on Forensic Science (NCFS) has called for accreditation of certification bodies in all areas of forensic science (NCFS 2017). Typically, certifications originate from a governmental agency or professional association. The well-known certifications in the fire investigation profession were listed in Chapter 2. There are also accrediting groups that review the certifications conferred by governmental agencies, higher education institutions, and other groups. As an example, the National Board on Fire Service Professional Qualifications (Pro Board) accredits fire service certifying processes. "The accreditation process begins with the submission of an application, including a detailed self-study document, by the organization seeking accreditation. The application package is then reviewed by the members of the Committee on Accreditation (COA) for completeness and compliance with the accreditation criteria of the Pro Board. The next step is a site visit by a team of COA members, usually two, who perform an extensive on-site review of the organization's testing and certification processes. The site visit team prepares a report and presents it to the COA. The COA decides if accreditation is granted." (http://www.theproboard.org/)

The International Fire Service Accreditation Congress (IFSAC) also accredits certifying processes and higher education fire-related degree programs similar to the Pro Board. The Eastern Kentucky University Fire, Arson and Explosion Investigation Bachelor of Science degree is the only fire investigation degree program accredited by IFSAC as of 2021.

Additionally, in response to a proliferation of forensic science certifications, the American Academy of Forensic Sciences (AAFS) incorporated the Forensic Specialties Accreditation Board (FSAB). The FSAB accredits ten certification programs, including the IAAI's certification program. Criteria for FSAB accreditation include: 1) An application process with a credentials check; 2) an examination process with demonstrated technical merit; 3) a recertification component requiring continuing professional development and 4) a Code of Ethics with a mechanism for withdrawing certification from a certified individual who violates that Code of Ethics.

8-3 Accreditation of Fire Investigation Units

The National Commission on Forensic Science (NCFS) has called for the accreditation of all forensic science service providers [NCFS 2017]. They identify both the benefits and challenges in this process.

OSAC was established to review existing forensic science standards to identify or create best practices or new standards that forensic science practitioners need to adhere to in their daily operations to facilitate a better criminal justice system that relies on solid science. The standards and best practices approved by OSAC can then be incorporated into an accrediting program with performance measures that fire investigation organizations should follow to become accredited.

Three well-known institutions accredit public safety organizations. The Law Enforcement Accreditation Program (LEAP) was established by the Commission on Accreditation for Law Enforcement Agencies (CALEA) to provide performance measures that law enforcement agencies can use to evaluate the operations of the organization. The Commission on Fire Accreditation International (CFAI) has developed performance evaluation categories for fire service organizations to conduct a self-assessment of their operations. CFAI defines accreditation as:

> *"a comprehensive self-assessment and evaluation model that enables organizations to examine past, current, and future service levels and*

internal performance and compare them to industry best practices. This process leads to improved service delivery" [CFAI 2017].

CFAI has a programs category within the overall accreditation process that addresses a fire investigation division in a fire department. The accreditation envisioned by the OSAC subcommittee is substantially more in-depth than what is available there.

As of 2021, there are four fire investigation agencies accredited to ISO/IEC 17020 by the American Association for Laboratory Accreditation (A2LA) or the ANSI National Accreditation Board (ANAB). "The Forensic Examination accreditation program was developed for those organizations that perform examinations of an item or location and, based on professional judgment, make a determination of conformity with proposed events or known conditions. In reality, any inspection performed could ultimately be meant for use in court. For example, a manufacturer may request an inspection of a manufactured item to help improve their product, but another customer may request the same inspection with the ultimate aim of using the results in a civil trial. The work isn't any different, but how one approaches the examination is. If the work is done incorrectly or if it is conducted by an untrained or incompetent employee, your report may be ruled inadmissible in court." [A2LA 2017]

The OSAC Fire and Explosion Investigation Subcommittee plans to act as a resource in developing a common set of performance measures that all fire investigation organizations should use. In 2016, the Subcommittee proposed that NFPA develop a standard for the organization and operation of a fire investigation unit and developed a first draft of the standard. NFPA accepted this proposal in 2018, and an NFPA committee began its work in 2019. It is envisioned that the NFPA standard (NFPA 1321) will be suitable as the basis document for accreditation of fire investigation units.

Stakeholders' input will be sought to assist in this development. By creating a common set of performance measures to be utilized by all Fire Investigation Units, and supported by the judiciary, the profession can minimize the risk exposure of inadequate fire investigations.

Overcoming Barriers for Fire Investigation Agencies to Become Accredited

It is well known that achieving accreditation is challenging in several respects. First, there must be a desire by senior leaders of the Fire Investigation Unit (FIU) to seek accredited status. To create this desire, some impetus in the form of an expectation by key stakeholders that the agency should be accredited needs to exist. The judiciary, prosecuting and defense attorneys, fire investigation associations, and others must set an expectation that operating without accreditation is outside the bounds of best practice.

In most cases, agencies will need to create documented policies and procedures that comport with individual performance standards. This is normally accomplished by the adoption of a quality assurance program. This is very resource-intensive and requires staff to be assigned to work on these documents. Additionally, there will likely be performance measures that will require additional funding for training, acquiring certifications, case reviews, and other needs. Most fire investigation agencies have very few staff, and these members may be required to perform fire code inspections and other duties in addition to investigating fires. It will be challenging for these agencies to develop and document a QA program and become accredited. It may be necessary to hire additional personnel whose sole responsibility is the development and documentation of a QA system. One way to overcome the challenges is by partnering with other FIUs in a region and establishing a county or area-wide team to allow for more staff to work on the accreditation project. The OSAC Fire and Explosion Investigation Subcommittee is currently developing a template Quality Manual complete with template Standard Operating Procedures and Guidelines for fire and explosion investigation units to facilitate FIUs developing the documentation needed for accreditation.

It is vitally important that any fire investigation agency be compliant with best practices. Accreditation is an important component of validating that an agency is assuring that their investigators meet NFPA 1033 requirements and investigate fires according to NFPA 921. An accreditation process creates an environment of continuous improvement based on national consensus standard best practices. Additionally, once an agency achieves accreditation through this independent third-party validation entity (the accrediting agency), the organization must submit annual reports on progress and be re-accredited in a defined period. Most agency accreditations last 4 or 5 years. This accountability is very important to ensure that the agency continuously meets the evolving performance measures in updated editions of the accreditation requirements. The continuous improvement process is ongoing. It is the OSAC Fire and Explosion Subcommittee's vision that in time, accreditation will become the norm in fire investigation units. In some jurisdictions now, public and private laboratories that are not accredited are prevented from participating in the criminal justice system (e.g., https://www.justice.gov/opa/pr/justice-department-announces-new-accreditation-policies-advance-forensic-science, http://www.txcourts.gov/fsc/accreditation/).

- Recommendation: *Require accreditation of fire investigation units by third parties based on an applicable consensus standard.*

8-4 Science Advisory Workgroup for Quality Control

This section reviews how the Texas State Fire Marshal's Office instituted a multi-disciplinary panel of experts, retrospective case reviews, post-conviction reviews, and working on a goal to establish proactive pre-trial case vetting to improve the quality of fire investigations. It provides a model for other fire investigation units.

Background

The Texas State Fire Marshal's Office (SFMO) found itself in a very difficult place in 2009. In 2006, The Texas Forensic Science Commission (TFSC) accepted its first complaint, submitted by the Innocence Project in the cases of Cameron Todd Willingham and Ernest Ray Willis. Both men had been convicted of arson and murder, and both had been sentenced to death. In 2004, Mr. Willis was granted a new trial and was later exonerated and compensated. Mr. Willingham was put to death. After two years of delay, and another year of a contentious investigation, the TFSC hired Dr. Craig Beyler, who, in 2009, prepared a report entitled *Analysis of Fire Investigation Methods and Procedures Used in the Criminal Arson Cases Against Ernest Ray Willis and Cameron Todd Willingham* [Beyler 2009]. The report detailed serious deficiencies in the quality of these fire investigations. In 2011, the TFSC published its report entitled *Willingham/Willis Investigation* that listed 17 recommendations to improve the quality of fire investigations in Texas [TFSC 2011].

The 17 recommendations were:

1. Adoption of National Standards
2. Retrospective Review of Cases
3. Enhanced Certification
4. Collaborative Training on Incendiary Indicators
5. Tools for Analyzing Ignition Sources
6. Periodic Curriculum Review
7. Involvement of SFMO in Local Investigations
8. Establishment of Peer Review Group/Multi-Disciplinary Team
9. Standards for Testimony in Arson Cases
10. Enhanced Admissibility Hearings in Arson Cases
11. Evaluating Courtroom Testimony
12. Minimum Report Standards
13. Preservation of Documentation
14. Dissemination of Information Regarding Scientific Advancements
15. Code of Conduct/Ethics
16. Training for Lawyers/Judges
17. Funding

In June 2012, Chris Connealy was appointed as State Fire Marshal by former Texas Insurance Commissioner Eleanor Kitzman. The SFMO is part of the Texas Department of Insurance (TDI). Chief Connealy immediately reviewed the Texas Forensic Science Commission reports, met with staff of the Forensic Science Commission and agreed to adopt all of the TFSC's recommendations. The first task was to determine if other fire investigation organizations had conducted retrospective case reviews using a multi-disciplinary team. After consulting with various fire investigation experts, he learned there were no operating programs that provide a model for a multi-disciplinary review team and a retrospective case review process.

Creation of the Science Advisory Workgroup

After numerous consultations with various experts in the fire investigation profession, the SFMO developed a multi-disciplinary team of fire investigation experts. The term "multi-disciplinary" refers to having a diverse group of experts with various backgrounds and credentials (e.g., criminalist, engineers, attorneys, public and private fire investigators, pathologist, chemist) to provide advice from the professions typically involved with fire investigations. TDI has been very supportive during this entire process. The agency provided funding to increase training of SFMO fire investigators and additional budgeting to establish contracts with the majority of the panel's experts. The SFMO decided to name its multi-disciplinary panel the Science Advisory Workgroup (SAW).

The SAW and Training

The SAW members are highly respected in their respective professions and represent diverse backgrounds that assist in training public and private fire investigators in the state. The Texas Forensic Science Commission issued the following recommendations related to training:

> *Collaborative Training on Incendiary Indicators – The Commission had concerns that various fire investigation myths were still being utilized by fire investigators as being indicative of incendiary fires such as crazing of glass, annealing of springs in furniture, spalling of concrete, low-level burning, the presence of "pour patterns" not confirmed by lab analysis, etc.*
>
> *Tools for Analyzing Ignition Sources – Once the origin has been determined, it is critical that fire investigators identify potential ignition sources. The investigator must utilize the scientific method to eliminate potential ignition sources.*
>
> *Dissemination of Information Regarding Scientific Advancements – The fire investigation profession has been negatively impacted by a lack of*

interaction and training with fire researchers to keep up with the latest discoveries of science related to the profession.

The SAW has taught numerous classes to dispel these myths through education and support of various reference sources. The SAW has provided classes on the analysis of ignition sources and additional insight gained through a review of past cases. The SAW aids in disseminating scientific advancements, utilizing the diverse backgrounds of the panel. All members of the SAW provide classes and feedback that allow fire investigators to keep up with the evolution of newly discovered science.

The improved level of training of the Texas SFMO and fellow fire investigators across the state is a key benefit of having the SAW. Some of the topics covered by SAW members during training over the past five years include:

Residential Wiring	Search and Seizure (Property &Evidence)
Fire Alarm Systems	Metallurgy
CSST and Energized Gas Line Fires	What to Expect Now That You are a Fire Investigator
Thermometry	Courtroom Ethics
Fire Investigations and K9s	Case Organization
Pathology of Fire Deaths	Fire Scene Documentation & Bilancia Matrix
Cyanide Inhalation	Failure Analysis and Analytical Tools
Preparing an Expert Report	Specialty Diagrams
Preparing Search Warrant Affidavit	Carcinogens in Smoke
Evidence Handling and Storage	Multi-meter
Water Heater Fires	Arc Mapping
Lab Techniques	HCN Levels
Fire Chemistry	ASTM Standards & Fire Investigations

Fire Dynamics	Fire Behavior
Practical Fire Modeling	Expert Testimony – Surviving NFPA 1033
Evidence – X-rays in Fire Inv.	Fourth Amendment & Fire Investigations
Cognitive Bias	Sixth Amendment
Scene Documentation/Aerial Vehicles	Thermodynamics
Explosion Dynamics	Electrical Systems

The SFMO implemented an aggressive training regimen comprised of hands-on training, lecture, and online education. The minimum training requirement that is part of the investigator's annual performance evaluation is 80 hours. The average investigator gets 100 to 130 hours of continuing education annually. The lack of a professional development plan that is focused on training, certifications, and other credentials, was a key factor that led to the problems exposed within the SFMO in 2009.

The SFMO has made the quarterly fire investigation forums with the SAW available to all fire investigators in the state and forums are presented at no cost to participants.

The Format of the Quarterly Fire Investigation Forums

All forums are structured as three-day events. The first eight-hour day is devoted to various training topics and is taught by SAW panel members. The second day consists of a block of four hours where panel members make 30-60 minute presentations to update attendees on various topics to keep fire investigators up to date on scientific advancements and to meet the requirements of NFPA 1033. After lunch, there is a four-hour block of retrospective case reviews. The third eight-hour day is devoted to retrospective case reviews.

It was quickly noted that the retrospective case reviews were very effective in helping the SFMO investigators become more proficient. The feedback from the SAW members was provided in a positive manner that created a coaching environment. They pointed out the good things the investigator did and provided constructive criticism to identify "opportunities for improvement."

Equally important, SFMO investigators were introduced to a case review process that none of them had ever experienced. The SFMO investigators deserve full credit for approaching the process with the utmost professionalism and a desire to become better fire investigators.

To say this was a difficult undertaking would be an understatement. First, no one had ever done this before. Second, the SFMO was being watched very closely by the media, government officials, the fire investigation community, and other stakeholders to see how the agency would approach these changes. Finally, with the SAW and SFMO working towards a common goal of continuous improvement, the intensive training and the retrospective case review process instituted an evolutionary model that keeps the agency moving toward excellence. Finally, it has been noted by the SAW that the quality of the fire investigation reports has been considerably improved when comparing older cases to more current ones.

As the SFMO and SAW progressively made the fire investigation forums/retrospective case reviews better, in 2015, local fire investigation agencies were allowed to bring their cases to the panel for review. In February 2017, the Laredo Fire Department brought one of their fire investigation cases to be reviewed. This exercise went very smoothly. It is hoped that other local fire investigation agencies will bring their cases to the SAW so they can benefit from the process as much as the SFMO has over the past four years. Other states have been invited to participate in the SAW.

Pre-Trial Case Vetting

Ideally, a pre-trial review of a fire investigation identifying erroneous findings before trial is far preferable to a post-conviction review. No prosecutor wants to convict an innocent person. The fact that findings by the SAW may be adverse to the State's arson case will be revealed to the defense should not be a reason to abandon the review. Texas has not found a means to implement pre-trial case vetting. Maryland is attempting to implement a system of pre-charging reviews organized by the SFMO and the Fire Prevention Commission. [Maryland State Fire Prevention Commission 2018]

IAAI and NASFM Endorsements

After learning about what the Texas SFMO was doing in this area to improve fire investigations, the IAAI formed a committee to determine if the organization should recommend these advances to their members. In December 2015, the IAAI Board of Directors recommended that their members use a multi-disciplinary panel and conduct retrospective case reviews to improve fire investigations [IAAI 2015]. The Executive Board of the National Association of State Fire Marshals (NASFM) also passed an endorsement to follow a similar method as the Texas SFMO [2017].

- Recommendation: *Require case reviews be developed and implemented, which can include retrospective and proactive reviews. A multi-disciplinary review committee can be used to assist with this process, such as the one implemented by Texas SFMO.*
- Recommendation: *Require fire investigation units to adopt a quality assurance system.*
- Recommendation: *Require all fire investigation reports to be subject to technical and administrative reviews. Case documentation supports the opinions within the report.*
- Recommendation: *Develop a consensus standard for the organization and operation of a fire and explosion investigation unit.*

8-5 Code of Ethics

IAAI and NAFI both have a Code of Ethics. There are also state and local fire investigation organizations that have codes of ethics. Creating a code of conduct/ethics was one of the seventeen recommendations of the TFSC to improve fire investigations. When researching a code of ethics related to fire investigations, it was revealed that there are similar statements in these documents. Codes of ethics are typically exhortations to be an ethical example to others, challenge the individual to learn more to be a better fire investigator, support professional standards, avoid actions that appear dishonest, be non-biased, seek to protect the innocent, and hold those accountable for arson. It is recommended that every fire investigation agency have a written code of ethics to define expectations of all members of the agency.

Violations, Complaints, and Resolution Process Related to the Code of Ethics

The implementation of a Code of Ethics requires a written procedure for handling complaints or misconduct. Such a procedure should be detailed, and provide the complainant, the respondent, and the body reviewing the complaint with a clear set of instructions on how to proceed. This includes notification of the respondent, investigating the complaint procedures for protecting confidentiality, and potential sanctions. Different players in the criminal justice system have different ethical obligations. These distinctions should be spelled out in the Code of Ethics.

- <u>Recommendation:</u> *Require fire investigation units to adopt a Code of Ethics.*

8-6 Conclusions

Certifications are only as good as the requirements to gain the credential. Governmental entities and associations that issue certifications should create a challenging process that stays current with the best practices of the profession.

There are distinct differences between competency and proficiency testing. Competency testing evaluates the skills, knowledge, and abilities that are part of a training program. Proficiency testing evaluates the fire investigator's overall performance. Both types of testing are needed to evaluate investigators during training and subsequent job performance.

Accreditation of fire investigation units is lacking. Third-party validation of an organization on how it meets the performance measures within the accreditation documents provide a structure to comply with best practices. This is urgently needed to avoid the well-documented challenges identified by the National Academy of Sciences, media, and other sources.

This chapter also discussed quality assurance recommendations to improve the fire investigation profession by establishing multi-disciplinary panels of experts to provide training and case reviews for organizations, to ensure that current science and best practices are always actively being pursued. The fire investigation profession must embrace these quality control recommendations to minimize risk exposure of poor investigations being sent to trial. Additionally, a proactive pre-trial case vetting process needs further consideration rather than just depending upon post-conviction reviews. Finally, the development of a code of ethics that guides the fire investigation unit in its daily operations, and recommendations on how to ensure this document is 'lived' by the organization was also presented. An adopted code of ethics by fire investigation organizations defines the expectations of the agency for its employees to follow in their daily operations. Leaders of these agencies must follow through to make sure these ethics are upheld.

REFERENCES

American Association for Laboratory Accreditation. (2017). https://www.a2la.org/accreditation/forensics

Beyler, C. (2009), Analysis of the Fire Investigation Methods and Procedures Used in the Criminal Arson Cases Against Ernest Ray Willis and Cameron Todd Willingham, Hughes Associates, Inc., for the Texas Forensic Science Commission. http://i.cdn.turner.com/cnn/2009/images/11/09/rpt.tx.forensic.willes.willingham.anaylsis.final.pdf

Center for Public Safety Excellence, Commission on Fire Accreditation International. (2017), Accreditation Overview.

https://cpse.org/accreditation/

Eine Antwort. (2011). *Competency vs. Proficiency Model*, Learning Paths International,
http://www.learningpathsinternational.com/blog/?p=5

International Association of Arson Investigators. (2015). *The International Association of Arson Investigators Endorses the Use of multidiscipline Science Review Panels*

Lentini, J. (2017) *Forensic Science Reform: Chapter 3-Arson*. Editors Koen, W, and Bowers, C, Elsevier.
https://storage.googleapis.com/production-constantcontact-v1-0-7/507/175507/IaE9rCjE/2b4aa107107c4febbdca2e5f14656cea?fileName=2017%20Confronting%20Inaccuracy%20In%20Fire%20Investigations-John%20Lentini,%20Rachel%20Dioso-Villa.pdf

Maryland State Fire Prevention Commission (2018), Minutes from 18 October 2018 meeting,
https://mdsp.maryland.gov/Organization/Documents/FPC%20Minutes%202018%2010%2018%20and%20Attachment.pdf

National Commission on Forensic Science-Views of the Commission, Certification of Forensic Science Practitioners (September 12, 2016).
https://www.justice.gov/archives/ncfs/page/file/905897/download

National Commission on Forensic Science (2017), Work Products of the FCFS,
https://www.justice.gov/archives/ncfs/work-products-adopted-commission

National Board on Fire Service Professional Qualifications (2017).
http://www.theproboard.org/

Texas Forensic Science Commission. (2011). *Willingham/Willis Investigation*
http://fsc.state.tx.us/documents/FINALWILLINGHAMREPORT0418113.44pm.pdf

9. EDUCATION AND TRAINING IN FIRE AND EXPLOSION INVESTIGATION

9-1 Introduction

Fire investigation is a recognized forensic science discipline that requires a high level of procedural knowledge as well as a working understanding of a variety of traditional scientific and engineering subjects.

In the United States, the educational and training requirements that someone should achieve before working as a fire investigator is primarily at the discretion of the employer. The employers of fire investigators vary considerably, ranging from local law enforcement or fire departments to federal agencies on the public side and fire protection engineering and investigation firms on the private side. Therefore, the employer-defined educational and training requirements vary widely and can range from virtually no training to multi-year training programs that include college degrees and courses and long-term apprenticeships.

The wide variation in training and education is a legacy of the rapid advancements in the science of fire investigation in the past several decades. In the past, fire investigation was a non-scientific investigative profession that was based upon anecdotal knowledge gained from experience and mentorships. Today, fire investigation is a highly technical field with published procedures [NFPA 921], and standardized qualification requirements [NFPA 1033]. Many organizations have not updated their training requirements to keep up with the increased knowledge and skills that fire investigators are expected to have.

A major challenge to educating fire investigators is that most had no scientific education before entering the field. This is because the majority of fire investigators in the United States had backgrounds as police or in the fire service, before transferring into the fire investigation profession.

9-2 Education and Training

The lines between training and education in the fire investigation profession are blurred, mostly due to the lack of institutions focused solely on fire investigations. Many professionals may have degrees in other fields, but then obtain training from a variety of organizations to help round out their education particular to this field.

In 2012, a survey was completed that evaluated the training and education levels of the profession [Tinsley & Gorbett 2012]. The survey had a sample size of approximately 600 self-selected professional fire investigators. The average reported years of experience of this group was 10.5 years, with nearly two-thirds of the group being public fire investigators. The education level reported was remarkably high, with over 75% of the respondents holding at least an Associate's degree and 50% having a Bachelor's degree or higher. The majority of these degrees (~50%) were in fire science and criminal justice fields of study, with only approximately 18% of the respondents having a degree in engineering or the physical sciences. The survey also showed that fire investigators participate in continuing professional development with the majority of the respondents receiving a minimum of 20 hours of continuing education per year.

Training is conducted on the state, national, and international levels. State agencies train to meet state requirements – typically loosely based on NFPA 1033. Many state agencies also certify investigators within their states based on attendance at this training. There are two professional associations that credential fire investigators at the international level, the International Association of Arson Investigators (IAAI) and the National Association of Fire Investigators (NAFI).

9-3 Qualification Requirements for Fire Investigators: NFPA 1033

The qualification requirements for Fire Investigators are defined in NFPA 1033: *Standard for Professional Qualifications for Fire Investigator*. NFPA 1033 has been in existence since 1987 and is currently in its sixth edition. (Fire investigator professional standards were included in the 1977 and 1982 editions of NFPA 1031, before NFPA 1033 became a standalone document in 1987.) NFPA 1033 is widely recognized and has been adopted by IAAI and NAFI as well as many public and private organizations.

NFPA 1033 is a consensus-based national standard that is published by the National Fire Protection Association. NFPA 1033 is updated on a 5-year revision cycle by a technical committee with representatives from a range of backgrounds. During each revision cycle, public input is requested for revisions to the standard. The committee may propose revisions, and public comments are accepted for proposed changes to the text. The committee considers all public input and every public comment and decides which changes to apply to the next edition of the standard.

The key components of the NFPA 1033 Standard are the *Job Performance Requirements* (JPRs). These JPRs define specific tasks that the investigators should be able to perform and describe the knowledge and skills required to complete each task.

Members of the fire investigation community have different views about which JPRs and education should be required for fire investigators. Some in the industry want to keep the educational requirements at the high school education level so that the profession can be open to as many people as possible. Others want to raise the educational requirements, so that fire investigators need a science degree to be qualified to opine on the origin and cause of fires. Despite these conflicting views, NFPA 1033 has evolved and required more qualifications with every revision.

The minimum education required by NFPA 1033 is a high school diploma. Some in the profession interpret this requirement as meaning that no additional formal education is required regardless of what classes were taken in high school. However, it is generally accepted that knowledge of scientific and engineering concepts is necessary to produce accurate determinations of the origin and cause of fires. The challenge is that not all curricula in high school require the scientific concepts or mathematics that are prerequisites to learning the highly technical topics required by NFPA 1033.

- Recommendation: *Fire investigators should complete college-level coursework in algebra, chemistry, and physics, and understand how these subjects relate to the behavior of fire.*

In the 2022 edition of NFPA 1033, a significant revison and re-ordering of the list of required knowledge was implemented at the request of the OSAC Subcommittee on Fire and Explosion Investigations. The list was moved from the administrative section in Chapter 1 to the introduction of JPRs in Chapter 4. The requirements now read as follows:

4.1.7 In order to successfully complete the tasks identified in the JPRs of sections 4.2 through 4.7, the fire investigator shall remain current in the subjects listed as "requisite knowledge" as they relate to fire investigations, which include the following.

(1) Fire science, including

a) Fire chemistry

b) Thermodynamics

c) Fire dynamics

d) Explosion dynamics

(2) Fire investigation, including

a) Fire analysis

b) Fire investigation methodology

c) Fire investigation technology

d) Evidence documentation, collection, and preservation

e) Failure analysis and analytical tools

(3) Fire scene safety, including

a) Hazard recognition, evaluation, and basic mitigation procedures

b) Hazardous materials

c) Safety regulations

(4) Building systems, including

a) Types of construction

b) Fire protection systems

c) Electricity and electrical systems

d) Fuel gas systems

There is an extensive new annex and entitled "Terms and Concepts" (Annex D), which is also based on a "public input" from the OSAC Subcommittee. While this annex is not part of the requirements of NFPA 1033 it is included to define the subjects and to place limits on the list of subjects, to describe how they relate to fire investigation, and to direct investigators to sources where the requisite knowledge can be obtained.

9-4 Current Sources for Fire Investigation Training and Education

Fire investigation training is available from many sources. The following is a summary:

Professional Training:

- National Fire Academy – The National Fire Academy offers four (4) classes for fire investigators and several other related courses for fire service personnel that are not fire investigators. R206 is a two-week class that provides an introduction to the many topics covered by NFPA 921 and NFPA 1033. R0255 provides an introduction to electrical systems. R0214 provides training in evidence collection for fire investigators. R0204 provides an introduction to fire dynamics and computer fire modeling.
- Many states have fire service and law enforcement training programs that include courses related to forensic science and fire investigation.
- Professional Organization Seminars- IAAI and NAFI provide regional and national conferences and training opportunities throughout the year.
- Employer-sponsored training – Many employers offer structured training programs for their fire investigators. There are also many *ad hoc* employer training events.

- CFITrainer.net is a free and tested online training program made up of many training modules in a wide variety of topics that are of interest to fire investigators.

Colleges and Universities*:*

While many colleges include a single course on fire investigation within their fire science programs for fire department personnel, only three (3) universities in the United States provide degree programs specific to Fire Investigation. Two Universities offer Bachelor of Science (BS) degrees and two offer Master of Science (MS) degrees.

- Eastern Kentucky University offers a BS degree in Fire, Arson and Explosion Investigation. The degree requires a total of 120 credit hours, including 59 credit hours in core courses and 14 credit hours in supporting courses. Two semesters of freshman chemistry, college algebra, and an intensive writing course are required
- The University of New Haven offers a BS degree in Fire Science- Fire/Arson Investigation. The BS degree requires 123 credit hours, including 71 credit hours in core courses related to fire investigation. The degree requires one-semester courses in freshman chemistry, non-calculus mathematics, written communications, and oral communications.
- The University of New Haven offers an MS degree in Fire Science- Fire/Arson Investigation. The MS requires 39 credit hours with no specific undergraduate degree required. There are 25 credit hours of required courses and 14 credit hours of fire science electives. There are no science or mathematics requirements.
- Oklahoma State University offers a Master of Science degree in Forensic Sciences with an Arson and Explosives Investigation Option. The MS requires 39 credit hours with no specific undergraduate degree required. There are 21 credit hours required courses and 18 credit hours of technical electives. There are no science or mathematics requirements.

The two BS degree programs provide a comprehensive education in fire protection and fire investigation. Both programs require non-calculus math courses as well as freshman chemistry and courses on building construction, fire protection systems, and fire science. Both programs also require coursework in general crime scene investigation and coursework specific to fire and explosion investigations. The OSAC Fire and Explosion Investigation Subcommittee website includes a table that describes and compares the courses offered at each University [OSAC Fire 2019].

A student interested in pursuing a Bachelor's degree in fire investigations, but who cannot or does not want to begin their education at one of the fire investigations degree-granting universities may be able to take courses that count towards their degree plan from a local college or community college. A student is encouraged to evaluate the degree from the degree-granting institution to determine what specific general education courses are required (i.e., chemistry, math, English) and focus on taking the equivalent courses that will transfer from their local college for these general education courses at the degree-granting institution. Many universities have online databases or catalogs that list many of their classes and their equivalent courses at other institutions. Therefore, a student should easily be able to identify equivalent courses. If the local college or community college offers courses specific to fire protection or fire science, it is best to contact the degree-granting institution to determine if any of these courses may transfer in for credit or to delay taking any of these courses until the student is at the degree-granting institution. There are many fire science programs around the United States that offer classes in fire protection or fire science, but those classes may not sufficiently prepare the student for the upper-level classes and would therefore not be accepted for credit at the degree-granting institution.

The two MS degree programs provide more focused coursework based upon the interests of the student. Both programs offer courses in fire science, risk, arson investigation, and forensic science. Each program also offers a variety of other courses such as fire protection systems, the chemistry of pyrotechnics, failure analysis, and many others. It is of note that neither MS program requires any specific mathematics or science courses. This severely limits the level of treatment of topics in these programs. The OSAC Fire and Explosion Investigation Subcommittee website includes a table that describes and compares the courses offered at each University [OSAC Fire 2019].

9-5 Path to Better Education

Additional degree programs specific to fire investigation should be designed and implemented at other institutions around the United States. A curriculum specific to fire investigation should be integrated into closely related fields of study to assist with those entering the field from other engineering and physical science degree programs.

For fire investigators to understand the scientific aspects of the profession, fire investigators should be required to complete coursework from an accredited academic institution that includes the following topics:

Math - Topics should include a review of algebra, trigonometry, basic analytic geometry, exponential and logarithmic functions, coordinates and graphs.

Chemistry – Topics should include the major concepts and theories required for an understanding of chemical phenomena, including atomic and molecular structure, gas laws, stoichiometry, changes of state, chemical bonding, solutions, and energetics in chemical reactions. Laboratory work should include quantitative measurements of solutions, synthesis, and identification of chemicals by physical and spectroscopic methods, and molecular modeling.

Heat Transfer – Topics should include the three modes of heat transfer: conduction, convection, and radiation, one-dimensional steady and transient conduction, analytical and numerical methods conduction problems, convection heat transfer under laminar and turbulent flow regimes, the general characteristics of radiation heat transfer as well as the properties of radiating surfaces and radiation heat transfer between surfaces.

<u>Thermodynamics</u> - Covers principles of classical thermodynamics by teaching about mass, energy, heat, work, and ideal and real thermodynamic processes. Topics should include first and second laws of thermodynamics, the ideal gas law, properties of real gases, and the general energy equation for closed and open systems.

<u>Fire Dynamics</u> - Covers the burning behavior of materials, heat transfer in fires, and the fluid dynamics related to fire-driven flows. Topics include pre-mixed flames, diffusion flames, ignition, extinction, fire growth, and flame spread over surfaces, fire plumes and ceiling jets, compartment fire dynamics, and smoke movement. Students should solve fire-related algebraic problems by hand as well as solving more complicated problems using zone models and field models.

<u>Electrical Wiring Theory and Practice</u> - Covers basic electrical theory for AC and DC circuits, residential and commercial building wiring, blueprint reading, branch-circuit installations, and service entrance installations. Applications and requirements taught are based on the National Electrical Code. Topics will include electrical circuit calculations, interpretation of plans, branch-circuit installations, feeder installations and calculations, service entrance calculations and installations.

9-6 Problems / Challenges / Proposed Solutions

There is a lack of uniformity on the amount and types of education and training that fire investigators are required to obtain and maintain. There is a lack of knowledge about NFPA 1033, and not everyone is aware that NFPA 1033 applies to the fire investigators in their organization. There is a lack of agreement in the fire investigation community about the depth of education that is required for the scientific subjects. People disagree about what is meant by "basic knowledge." It is the Subcommittee's hope that the revised NFPA 1033 will help to clear up this lack of agreement.

The work product of many fire investigators is not regularly subjected to challenging technical review. This can result in the perpetuation of bad habits and poorly documented investigations. Scientific advisory workgroups, as outlined in Chapter 7, provide opportunities for investigators to defend their work product and learn from past experiences technically.

Most fire investigators very rarely testify in court, and the first time that many investigators are subjected to a challenging review of their work is when an investigation is going to court. This has the potential of impacting court outcomes. Mock *Daubert* motions and trials provide investigators the opportunity to better prepare for such hearings.

- Recommendation*: Fire investigation units should establish a formal process for fire investigators' work to be subjected to challenging technical review. This system should include both a review of written investigation records and reports as well as a verbal review that simulates testimony in depositions and trials. Investigators should be required to submit their work to this process routinely.*

While NFPA 1033 requires that each investigator remain current, there are no requirements for fire investigation units to provide training for the fire investigators nor are there guidelines for what types of training should be provided.

- Recommendation*: Fire Investigation Units should be required to establish a program that provides sufficient training and continuing education for fire investigators to meet the knowledge and Job Performance Requirements of NFPA 1033.*

There are many seminars available to fire investigators. The problem is that most of the seminars are taught at an introductory level, and there is no path for increasing knowledge past the introductory level. Investigators often attend multiple introductory seminars on a topic, but still, have no advanced skills in that subject area.

There is minimal proficiency testing. The Fire Investigation professional organizations require ongoing training, but there is no testing to determine whether the investigator's knowledge is increasing or even meeting minimum standards after their initial certification.

- Recommendation*: Continuing education should be mandatory with a requirement for proof that an investigator is learning up-to-date information and can reliably apply this information in the context of the scientific method.*

- Recommendation*: More competency and proficiency training and testing focused on specific knowledge and skills should be developed for fire investigations.*

9-7 Conclusions:

Successfully determining the origin and cause of fires requires a wide breadth of practical knowledge and skills as well as useable knowledge of scientific subjects. The knowledge and skills that are required are defined in the NFPA 1033 Standard. The challenge is that most individual fire investigators in the United States lack the scientific knowledge required by NFPA 1033.

New training and proficiency testing programs should be implemented to assure that fire investigators have the skills and knowledge to come to the correct conclusion about the causes of fires.

REFERENCES

NFPA (2022): *Standard for Professional Qualifications for Fire Investigator*, NFPA 1033, Quincy, MA. http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=1033

NFPA (2017): Guide for Fire and Explosion Investigations, NFPA 921, Quincy, MA. http://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards?mode=code&code=921

OSAC Fire and Explosion Investigation Subcommittee (2019), Comparison of Fire and Explosion Investigation BS and MS Programs. https://www.nist.gov/document/comparison-fire-investigation-academic-programsdec2019

Tinsley, A., and Gorbett, G. (2012). Fire Investigation Origin Determination Survey. Fire and Arson Investigator, Journal of the IAAI. 63 (4): Crofton, MD. https://ssem.eku.edu/sites/ssem.eku.edu/files/files/Gorbett%20-%20FIRE%20INVESTIGATION%20ORIGIN%20DETERMINATION.pdf

10. CONCLUSIONS

In 1979 the NFPA Committee on Fire Reporting recommended the establishment of a project on fire investigation [NFPA 1979]. This resulted in the formation of a new committee on fire investigation in 1985 [NFPA 1985]. This committee published the first edition of NFPA 921, a *Guide to Fire and Explosion Investigation*, in 1992 [NFPA 1992]. Much progress has been made since the early recognition of the need to enhance the practice of fire and explosion investigation. Today there is much that remains to be done. The field of fire and explosion investigation can now be said to be in its adolescence, but much work is required to bring it to maturity.

In terms of the impact of NFPA 921 on fire-related litigation, progress has been far more rapid in civil litigation than in criminal matters. The courts have exercised their gatekeeper role in civil litigation far more rigorously than in the criminal courts. In civil litigation, the combination of *Daubert* and NFPA 921 have jointly improved the quality of expert witness testimony in fire investigations significantly. This cannot be said in criminal matters. Courts have been reluctant to rigorously exercise their gatekeeper role in criminal matters [NAS, 2009]. Judges and lawyers need to be educated and trained on fire science and investigation to assure that only high-quality fire investigations and analyses are presented to juries. Both as a result of poor gatekeeping and poor funding of public fire investigation units, progress in the improvement of fire investigation in the public sector most relevant to criminal matters has been slow.

The core of NFPA 921 is the scientific method. The scientific method provides the framework in which the origin and cause of the fire are determined. Over the nine editions of NFPA 921, there has been ongoing progress in refining the application of the scientific method and in the application of fire science to fire and explosion investigation. NFPA 1033 has taken its place in defining the qualifications of fire and explosion investigators.

While fire and explosion investigation certifications are in place, there is a need to move to the point where all fire investigators are certified. Also, there is a need to improve the certification process continuously and to demonstrate that certification leads to improved quality of investigations.

To date, there has been little attention given to the structure and operations of fire investigation units in supporting quality fire investigations. To initiate a focus on fire investigation unit operations, in 2016 the OSAC Fire and Explosion Investigation Subcommittee proposed that NFPA develop a standard on the *Organization and Operation of Fire Investigation Units* [Beyler 2016, NFPA 2017]. In 2017 the proposal was accepted [NFPA 2017a]. In 2018 committee members were selected, and the committee began its work in 2019. The proposal for the standard included requirements for an organization, for facilities and equipment, for compliance with safety procedures, for training, certification, and education, for origin and cause report content, for document retention, for review and approvals of investigation reports, and processes and management systems. It is anticipated that the proposed standard will be suitable to support and provide a path to accreditation of fire and explosion investigation units.

Developing a standard specifically for accreditation of fire investigation units is an important step in fulfilling the National Academy of Science [NAS 2009a] call for all forensic work to be carried out in accredited organizations. In April 2015, the National Commission on Forensic Science echoed this call for universal accreditation of forensic science service providers, including fire investigation units [NCFS 2015]. The field of fire and explosion investigation needs to move toward accreditation of all fire and explosion investigation units under the NFPA Standard when it is completed. All fire and explosion investigators need to be certified and follow standard methods while working within an accredited fire and explosion investigation unit. There is a need to create an environment in all fire and explosion investigation units of continuous improvement. The Science Advisory Workgroup concept, as developed in Texas, has great promise to enhance the quality of fire investigations. Such quality improvement mechanisms need to be instituted throughout the country.

In conjunction with the increased focus on fire investigation unit operations, there is a need to institute measures to enhance investigation quality. The days of individual investigators working alone are coming to an end, in favor of a team approach to fire investigation. The team approach recognizes the complexity of fire investigations, the need for cooperation for safe and effective operations, and the need to reduce the potential for bias through the management of data collection and analysis. Fire and explosion investigation units need to implement information management practices to minimize bias and exposure to task-irrelevant data. Also, there is a need for fire investigation units to fully implement the scientific method and technical review processes to minimize potential bias. All stakeholders need to take responsibility for requiring complete and comprehensive fire and explosion investigation reports, including all data collected, all hypotheses formulated, details of the testing process for each hypothesis, and the conclusions of the investigation.

Sustained funding for fire and explosion investigation research is needed to move the discipline forward. The research agenda detailed in Chapter 7 needs to be implemented. Research is needed in areas from the fundamentals of fire dynamics to the implementation of investigative tools. Particular focus is needed on the development of protocols and establishment of error rates for the protocols used in fire and explosion investigation. Research is further needed to develop methodologies that minimize the potential for bias. Efforts are required to assure that research for fire investigation is easily accessed by investigators.

It has become clear that the traditional educational requirement of only a high school education can no longer be accepted. The 16 knowledge areas which bear on fire and explosion investigation are too sophisticated for investigators to master the needed science and technology working simply from a high school education. It must be acknowledged that fire is a collection of complex physical and chemical processes that necessitates investigation by those educated in the science and practice of fire and explosion investigation. Today fire and explosion investigation is somewhat unique among the forensic sciences in requiring only a high school diploma to practice. There currently exist only limited opportunities for college-level education for fire investigations. There is a need to expand the number of such programs. The day when a BS in one of the physical sciences, engineering, or Fire and Explosion Investigation is the entry-level educational requirement needs to be realized in the coming years.

While great progress has been made since the 1980s, there remains much to be done. This strategic vision identifies the work that is needed in the field of fire and explosion investigation in the coming years. Over time, these recommended actions are achievable with direct action and sustained attention. The day in which NFPA 1033, 921, and a fire investigation unit standard are used in an integrated manner by certified fire and explosion investigators with sufficient education in the discipline, working in accredited fire and explosion investigation units, routinely produce high-quality investigations and reports under the watchful eyes of gatekeepers can be envisioned. It remains for us as a community to work toward achieving that end in the coming years.

REFERENCES

Beyler, C. (2016), Proposed Standard for the Organization and Operation of Fire Investigation Units, NFPA New Project Initiation Form, on behalf of the OSAC Fire and Explosion Investigation Subcommittee.

National Academy of Science (2009), Committee on Identifying the Needs of the Forensic Sciences Community; Committee on Applied and Theoretical Statistics, National Research Council, Strengthening Forensic Science in the United States: A Path Forward, p. S-8. https://www.nap.edu/initiative/committee-on-identifying-the-needs-of-the-forensic-sciences-community

National Academy of Science (2009a), Committee on Identifying the Needs of the Forensic Sciences Community; Committee on Applied and Theoretical Statistics, National Research Council, Strengthening Forensic Science in the United States: A Path Forward, p. 215. https://www.nap.edu/initiative/committee-on-identifying-the-needs-of-the-forensic-sciences-community

NCFS (2015), Recommendation to the Attorney General, Universal Accreditation. https://www.justice.gov/archives/ncfs/file/477851/download

NFPA (1979), Letter from the NFPA Fire Reporting Committee to the NFPA Standards Council, Item 79-39 Attachment 3, March 14, 1979.

NFPA (1985), NFPA Standard Council Minutes Item 85 – 59.

NFPA (1992), *Guide for Fire and Explosion Investigation*, NFPA 921, National Fire Protection Association, Quincy MA. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=921&year=1992

NFPA (2017), Fire Investigation Units (FIUs), *Fire News*, Vol. 21(10), p2

NFPA (2017a), Standards Council Meeting Final Minutes, Meeting of December 2017, Item 17-12-38 https://www.nfpa.org/-/media/Files/Codes-and-standards/standards-council/December-2017/SC_Minutes_12_17.ashx?la=en