Fire Scene Inspection Methodology and Collection of Evidence

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Abstract

This article describes a methodology for the safe and appropriate examination of fire scenes, including the planning of the inspection, collection of relevant evidence and data, analysis of that data, and the formulation and testing of hypotheses as to the origin and cause of the fire.

Glossary

Accelerant Any substance, usually a flammable or combustible liquid, that is used to initiate or spread a fire.

Flashover A transition phase in the development of a fire in a structure, in which all combustible surfaces exposed to thermal radiation ignite more or less simultaneously and fire spreads rapidly throughout the space, resulting in full room involvement. The transition is from "a fire in a room" to "a room on fire".

Flash point The temperature at which a still pool of liquid will produce sufficient vapors to ignite when exposed to a competent ignition source.

Fuel-controlled fire A fire in which the heat release rate and growth rate are controlled by the characteristics of the fuel, such as quantity and geometry, and in which adequate air for combustion is available.

Full room involvement A compartment fire in which the entire volume is involved in fire, but flaming will only occur when there is sufficient oxygen available.

Ignitable liquid A liquid that is capable of burning, often a petroleum-based product. Ignitable liquids may be flammable or combustible. Flammable liquids are those having a flash point below 37°C. Combustible liquids are those having a flash point above 37°C.

Series arc An arc caused by current flowing in its intended path that encounters a point of high resistance, usually at a loose connection.

Spoliation Loss, destruction, or material alteration of an object or document that is evidence or potential evidence in a legal proceeding by one who has the responsibility for its preservation.

Ventilation-controlled fire A fire in a postflashover compartment, where all fuels are involved, and the heat release rate of the fire is controlled by the availability of oxygen.

Key Points

- Planning is essential for a safe and effective fire investigation.
- Documentation is crucial to accurately convey the investigator's findings.
- The heaviest damage in a structure fire is the result of the greatest energy input to the structure. In fully-involved fires, this is usually not be where the origin is located.
- Understanding the ventilation is critical to understanding the fire behavior.
- When collecting samples for ignitable liquid detection, comparison samples are almost always necessary because of the exquisite sensitivity of modern fire debris analysis laboratories.

Introduction and Overview

Because each fire is different, specifying an exact methodology for a fire scene inspection is difficult, but there exist sufficient similarities among fires to make it possible for the investigator to develop a standard approach. Not every step described in this article will be necessary for every fire, and many of the routine steps described can only be carried out by the first responder.

Procedures will vary according to the problem a fire investigator is asked to address. Usually, the problem is to determine the origin and cause of the fire, but often there are additional questions that need to be addressed, such as the reason for a victim's failure to escape, the reason for a fire detection or suppression system's failure to function, or the reason for an unusually rapid spread of the fire.

In some cases, the origin and cause of the fire are obvious, usually when the fire fails to become fully developed, and it is only the secondary questions that require any significant skills to address.

Although many fire investigators began their careers as firefighters, there are significant differences in the skill sets required to extinguish a fire and those required to investigate a fire. Extinguishment officers are 100% effective at putting out fires. Fire investigators, on the other hand, must sometimes accept the reality that the determination of the origin and cause can be an impossible task, due to the complexity of fire behavior.

First Assumptions

More than 80% of fires are accidents, and because the consequences of declaring an accidental fire to have been intentionally set are so serious, there is a lively debate in the fire investigation community about what should be presumed. In some jurisdictions, it is the law that all fires are presumed accidental until proven otherwise, but the fire investigation community has taken the position that fire investigations should be approached without any presumptions. See NFPA 921, *Guide for Fire and Explosion Investigations* at §4.3.8.

Planning the Investigation

It is necessary to gather sufficient information to formulate a workable fire scene inspection plan. When the assignment for an investigation is first received, the investigator needs to know what resources will be necessary to process the scene. Additionally, it is necessary to identify "interested parties", (e.g., neighbors who sustained damage, contractors, insurance companies) and to learn the use (occupancy) of a structure. Certainly, public-sector investigators have different responsibilities from private-sector investigators. Often, the public-sector investigator's work is done once the determination has been made as to whether the fire was the result of a criminal or an accidental cause. Private sector investigators are often working for clients who are interested in exactly what caused the fire, so that responsible individuals or manufacturers can be held accountable through subrogation.

Because fires can sometimes be so complex, there are times when an investigator's skill set may limit the questions they are capable of addressing. It is often necessary to arrange for additional personnel such as fire protection engineers, or structural and electrical engineers. In commercial or industrial occupancies, heavy equipment may be required to process the scene.

It is a good idea to learn as early as possible whether there were any eyewitnesses to the fire, and whether any of them photographed or videotaped the fire in progress. If a security system exists in the building, records of alarms or even videotapes of the fire in progress may be obtainable from the alarm-monitoring company.

It is also important to ensure that the investigator has the authority and the right to enter the property to conduct the inspection. Such authority usually comes in the form of permission from the owner to enter the building, but a search warrant may be necessary in some cases.

Initial Evaluation: Can This Inspection Be Conducted Safely?

Fire scenes are dangerous places and must be approached with caution. Because the mission of the investigator is not urgent, there is no need to compromise safety. The emergency is over. The fire has been extinguished and there is nobody to rescue. If possible, fire scene inspections should not be conducted at night. The scene should be secured until there is adequate light to conduct the fire inspection safely and to make the necessary observations.

Obvious fire scene hazards include structural instability, energized electrical circuits, and leaking fuel gases, but there exist less obvious hazards that the investigator must consider. These include fire gases such as carbon monoxide and hydrogen cyanide, and hazards such as asbestos and biohazards. Appropriate personal protection equipment such as boots, gloves, and respirators are essential.

The initial survey of a fire scene usually begins with the exterior of the building and moves to the interior. It is best to move from the area of least damage toward the area of greatest damage, to avoid developing a case of "tunnel vision", and to make certain that all of the building has been examined. It is during this initial walkthrough that the investigator can plan for the documentation and reconstruction of the fire scene. At this point, however, the investigator should avoid forming hypotheses about the fire if possible.

Documentation

Documentation is the most important task in a fire investigation. At some point, a jury may be asked to review that documentation and agree with the fire investigator's interpretation, but documentation is important for its own sake. Regardless of when the investigator arrives at the scene, be it minutes, hours, or months after the fire, the investigator should document the entire scene prior to making any changes.

Photographs represent the most important form of documentation, and now that images are practically free, there is no reason to limit the number of images collected. Digital cameras collect data about the order in which photographs are taken and the amount of time passed between the first and last photograph. A logical, well-organized investigation is reflected in the photographic record.

The documentation typically moves from the exterior to the interior. All ventilation openings should be photographed and characterized as to whether they represent an opening that acted as an intake, an exhaust, or both. Inside the structure, moving from the least damaged area to the most heavily damaged area will ensure that the entire structure is examined. The most heavily damaged area may not be the origin of the fire because the damage may be the result of increased ventilation or delayed extinguishment.

Close-up photographs are necessary in many cases but need to be placed into context. This is accomplished by taking an overall view of the item of interest, prior to zooming in on it.

Other forms of documentation are also necessary for a proper investigation. Written notes allow the documentation of those data not suited to photography, and video images frequently help to orient the photographs. All documentation is evidence and should be maintained until all litigation is resolved.

A critical piece of documentation that is required on all but the simplest fire scenes is the sketch. In most instances, the minimum sketch should be a floor plan. Ready-made sketches may be found in the form of escape plans posted in commercial or business occupancies. A sketch is absolutely essential in order for readers of an investigator's report to understand what they are looking at. Graph paper, ruled in bold lines in 2.5 cm^2 and fine lines in 2.5 mm^2, makes the task of sketching much easier.

The level of detail required in the sketch will be dictated by the needs of the fire investigation. In many cases, a plan view showing the rooms and doorways is all that is necessary. If ventilation is an issue, and it usually is, windows are not difficult to add. If computer modeling is contemplated, however, it is not only necessary to draw the doors and windows, but to record the height of each opening, the height of all ceilings, sills, and overhangs, and the composition of the interior finish throughout. Additionally, the location of each fuel package in the room must be recorded.

Sketches should be oriented to the earth using a north arrow. An approximate scale is also essential to any sketch.

During the documentation of the scene prior to any disturbance, the investigator can make the observations necessary to help him or her decide how to reconstruct the scene. It is in this preliminary documentation that the utilities should be observed. Interior and exterior finishes can also be documented at this point. The use of a checklist of common building features is recommended so that both the important and unimportant data can be recorded. It may be that the natural gas water heater had nothing to do with the fire, but if the investigator is unable to correctly answer a question about the water heater, his credibility is likely to be impaired.

Reconstruction

Reconstruction is carried out in order to recreate, as nearly as possible, the position of various structures and fuel packages prior to the fire. Fire patterns on items that have been moved can be much more easily understood if these items are put back into place.

Although it is sometimes necessary to use heavy equipment to remove fallen structural materials, in most cases, the best tool is the flat-headed shovel. It may take ten such shovels and several wheelbarrows to remove the debris and expose the original interior surfaces. Such work is dirty and time-consuming, but it is during this reconstruction process that valuable evidence is uncovered.

The most valuable evidence is that which shows sequential data. A fire scene records everything that happened during the course of the fire from beginning to end, but most patterns do not come with time stamps. Often, the best that can be hoped for is to determine which object fell down first or what position an object was in when it was sprayed with water. Sections of ceiling material that have fallen can be examined to determine whether there was more damage on the top or the bottom. Protection patterns caused by falling debris can also provide clues as to how the fire progressed.

Once debris has been moved, items should be placed back in their original locations, if possible. This can be particularly difficult with square or round-bottomed objects, as it is possible to reposition them exactly backward from their original location.

Once reconstruction has been completed, any portions of the scene that have been changed during the process must be documented again.

Once reconstruction is completed and documented, the fire investigator has likely seen all the physical evidence there is to see. The work that has been done should allow for the development of a credible hypothesis as to where the fire started and a second credible hypothesis as to what caused it. But there are other steps that intervene.

Inventory

It is often necessary to make an inventory of the items that were present in a structure at the time of the fire. Such an inventory may serve to document the fuel load. Also, the investigator can determine whether the inventory is consistent with the reported occupancy.

Inventory may also reveal the prior removal of contents or even the substitution of contents. The unexplained absence of valuable items or the substitution of valuable items with replacements of lesser value raises the possibility that someone had prior knowledge of the fire.

The interpretation of the inventory requires considerable caution. Fires destroy combustible items, and many of them may be completely consumed or unrecognizable after a fire. This does not necessarily mean those items were not present. It is far easier to prove the presence of an item than to prove its absence.

Avoiding Spoliation

Fire scenes are evidence, and evidence needs to be protected. This is particularly true with respect to civil cases where one party may seek to hold another party liable for monetary damages caused by a defective product or service. When an investigator reaches the point where it appears that he or she can identify a responsible party, fairness and the law require that they stop and allow the potentially responsible party an opportunity to review the evidence in place. This may require delaying further investigation for several days or even weeks, particularly if multiple parties sustained damage or are suspected of playing a role in causing or spreading the fire.

The fire investigation community has carefully considered the concept of spoliation, and has concluded that certain activities, such as debris removal, or opening a suspected appliance in order to identify the manufacturer should not be considered spoliation. Additionally, it may be necessary to move potentially causative agents from the scene in order to protect them from further damage.

Spoliation is an issue that is generally not applicable in criminal fire investigations, although there have been some cases where public agencies have been held responsible for allowing evidence to be destroyed and depriving a potential defendant of his right of confrontation under the sixth amendment.

Origin Determination

The determination of the point of origin is the fire investigator's most important and most difficult task. It is axiomatic that if the origin of the fire is not determined correctly, the cause will also be incorrectly determined. Generally, there are three categories of evidence that must be considered by the investigator in helping to locate where the fire started. These are:

(1) Witness observations or video recordings
(2) The analysis of fire patterns including patterns created on the electrical system
(3) The consideration of fire dynamics

Witness observations may be crucial for determining where the fire started. Particularly in the case of full room involvement, a witness statement may be the only evidence that allows the origin to be pinpointed. Witnesses may also help the investigator understand the arrangement of furniture and other items in the structure prior to the fire.

Investigators should be cautious when their interpretation based on fire patterns varies significantly from what witnesses have observed. Some experiments on the validity of origin determination using fire patterns have produced disturbingly high error rates. Other data that can be characterized as witness statements include video of the fire in progress and alarm system functions.

A word about the proper use of witness statements is in order. When determining the origin and cause of the fire, the investigator should consider only those statements that have a bearing on fire science. The power of science in revealing the truth rests on the independence of the evidence. This independence can be compromised by statements having nothing to do with the physical evidence, such as inculpatory statements made by a suspect to a third party either before or after the fire. The consideration of such statements results in contextual bias and can lead to errors in interpretation of the artifacts at the fire scene.

The mechanisms by which fire patterns are created and how they might be interpreted to lead an investigator to the origin are discussed elsewhere in this encyclopedia. Confinement patterns, movement patterns, and intensity patterns can all be useful indicators of how a fire moved. It is useful to place arrows on the sketch indicating the movement of a fire.

It is very important to consider which patterns may be the result of postflashover ventilation-limited burning, which may well have absolutely no meaning with respect to the origin.

The following is a checklist of activities to be conducted when determining the origin of the fire. This checklist follows the basic format of the scientific method.

1. Data Collection

Basic site data
Determination of pre-fire conditions
Fire department information
Alarm, detector, and security data
Documentation of postfire conditions
Witness statements and observations
Excavation, examination, and reconstruction of the scene
Documentation of post reconstruction conditions

2. Data Analysis

Damage assessment (Which rooms became fully involved?)
Fire pattern analysis
Heat and flame vector analysis
Depth of char and calcination surveys
Electrical arc mapping
Event sequencing
Fire dynamics considerations
Analysis of ventilation openings (inlet, exhaust, or both?)
Building construction and occupancy considerations

3. Hypothesis Development

Initial origin hypothesis
Working origin hypotheses
Alternate hypotheses

Once an origin hypothesis has been developed, it must be tested against the evidence. There are four questions that an investigator should ask once he or she has formed a hypothesis as to the origin of the fire. These are:

(1) Is there a competent ignition source at the origin?
(2) Does the origin explain the data?
(3) Are contradictions resolved?
(4) Does an alternate origin explain the data equally well?

If there is no competent ignition source found at the origin, it is likely that the proposed origin is incorrect. The same is true for the absence of a competent fuel source at the hypothesized origin. There is a temptation on the part of some investigators to conclude that the ignition source must have been an open flame that was carried away by the person who set the fire, and the fuel source was an ignitable liquid poured on the floor, which was completely consumed by the fire. It is this type of determination that results in serious errors. In cases of full room involvement, it is often not possible to define the origin as an area smaller than the entire room.

The next question asks whether an origin in the hypothesized location explains how the fire spread from there and damaged the rest of the structure.

It is an unusual fire scene that does not contain some contradictory information. The investigator needs to attempt to resolve conflicting information; for example, if the electrical system shows signs of failure far away from where the origin is hypothesized and there is no evidence of electrical activity in the hypothetical origin. Regardless of the fire's cause, energized electrical conductors in the area of origin that are exposed to flames are likely to exhibit evidence of melted conductors.

Finally, the investigator needs to consider alternate origins that might explain the data equally well.

Cause Determination

A fire cause is defined as the circumstances, conditions, or agencies that bring together a fuel, ignition source, and oxidizer (usually air) resulting in combustion. The determination of a fire cause requires the identification of those factors that were necessary for the fire to have occurred. Those factors include the presence of a competent ignition source, the type and form of the first fuel ignited, and the circumstances that allowed the factors to come together and start the fire.

As with origin determination, cause determination must follow the scientific method. The investigator should carry out the following activities.

1. Data Collection

Document the fuels in the area of origin
Document all potential ignition sources
Identify the oxidizing agent (usually this is atmospheric oxygen)
Identify the circumstances that brought the fuel, ignition source, and oxidizer together

2. Data Analysis

Analyze the fuel (How much is present? How easily is it ignited?).
Analyze the ignition source (Does it have sufficient energy to cause ignition? Did it exist for a sufficient period of time to cause ignition?)
Analyze the oxidizer, especially if other than air
Analyze potential ignition sequences

3. Hypothesis Development

Propose a separate hypothesis for each potential ignition source
Consider absent ignition sources
Propose a first fuel for each ignition source
Consider alternate hypotheses

Once a cause hypothesis has been developed, it must be tested against the evidence. These are the questions that an investigator should ask once he or she has formed a hypothesis as to the cause of the fire:

(1) Is (or was) the hypothesized ignition source located at the origin?
(2) Does the hypothesized ignition source have sufficient energy to ignite the first fuel?
(3) Did the hypothesized ignition source have sufficient time?
(4) Is the hypothesized cause consistent with all known facts?
(5) Are contradictions resolved?
(6) Does another cause hypothesis explain the data equally well?

The determination of the fire's cause should be based on evidence, rather than an absence of evidence. There has been a tendency on the part of some investigators to declare that because they could find no accidental cause for the fire, it must have been intentionally set, even when there is no evidence of incendiary activity. Such determinations are referred to as "negative corpus" determinations. Negative corpus determinations are a violation of the scientific method because they result in untestable (i.e., invalid) hypotheses. The proper classification of the cause of a fire for which there is no evidence to support a classification of either accidental or incendiary cause is undetermined.

Evidence Collection at Fire Scenes

Evidence collected from fire scenes can take many forms. The most common type of evidence collected at a fire scene is material suspected of containing ignitable liquid residues (ILRs). Other evidence that may be collected for ILR analysis includes comparison substrate samples, liquid samples for comparison, or suspect's clothing and shoes.

Suspected ignition sources, such as incendiary devices or appliances suspected of malfunctioning, are also frequently collected in an attempt to test the field investigator's hypothesis about the origin and cause of the fire.

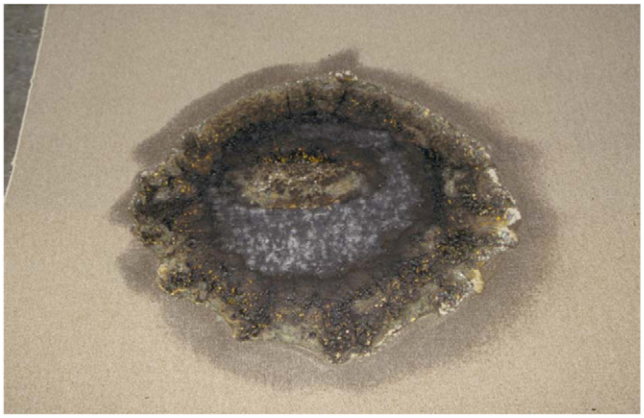

Fig. 1 “Doughnut” pattern produced by gasoline burning on carpet.

The identification of an ILR in a sample of fire debris can support a field investigator's hypothesis regarding the incendiary nature of a fire. The identification of such a liquid residue in a fire scene, however, does not necessarily lead to the conclusion that a fire was incendiary in nature. Further investigation may reveal a legitimate reason for the presence of flammable or combustible liquids.

Due to the volatility of ignitable liquids and the variations in sampling techniques, the absence of detectable quantities of flammable or combustible liquid residues does not necessarily lead to the conclusion that flammable or combustible liquids were not used to accelerate the fire.

In order to have any utility, samples collected for ILR analysis must be properly packaged and labeled prior to submission to the forensic science laboratory.

Sample Selection and Documentation

In arson cases, it is common for the arsonist to accelerate the fire by pouring ignitable liquids throughout the structure. Typically, the liquids are poured on the floor, so flooring, if it survives, is what fire investigators usually sample. Selecting a sample that is likely to test positive for ILR (assuming there is any present) requires care, practice, and luck.

Where ignitable liquid has been used, it is often present in overabundance and it may be easily detectable by odor, once the floor has been cleared of fallen debris. It is also possible to see where the ignitable liquid was poured by observing the damage patterns on the floor.

On carpeted floors, there is often a distinct line between burned and unburned areas, although such lines are common in cases where no ignitable liquid was present. Further, because of the way air is entrained into the fire plume of a piece of burning carpet, there tends to be a “doughnut” pattern produced. This results in carpet at the center of the area saturated with ignitable liquid being less damaged than carpet at the edge of the area. Fig. 1 shows a typical doughnut pattern. Obviously, the “doughnut hole” presents the best sample. When no “doughnut hole” exists, the sample should include both burned and unburned carpet from the edge of the pattern to its middle.

On hardwood floors, ignitable liquids tend to run in the cracks, as shown in Fig. 2. Vinyl floors also may exhibit extra burning where the ignitable liquid has penetrated into seams or lower parts of a textured floor, as shown in Fig. 3.

Sample size is usually dictated by the size of the available sample containers. A sample container of 1–5 liters will usually be adequate. It should be noted that because the laboratory analysis will usually involve sampling the headspace in a container, filling the container completely is not advisable. If the container is filled completely, it will be necessary for the laboratory to repackage the debris into a larger container for analysis.

When collecting samples, it is imperative that the investigator takes steps to avoid cross contamination or even the appearance of cross contamination. If the tools used for sampling are the same tools used for debris removal, those tools should be decontaminated prior to sampling using a detergent solution. Tools should be cleaned off in between samples to avoid carrying liquid residue from one place to another. If the investigator has any sense of where in the scene there is a higher concentration of ILR, that area should be sampled after the less concentrated areas are sampled.

If arson is suspected, gasoline-powered tools should not be brought into the fire scene. If power is required, a generator should be used for electric tools and the generator should be kept outside. Fire extinguishment crews should be asked whether gasoline-powered fans were used on the fire, and whether it was necessary to refuel the fan at any time. Such data should be documented.

The most important attribute of any fire debris sample is its location. When the investigator makes the decision to sample a particular area, that area should be thoroughly photographed, and the location of each sample should be documented on the investigator's fire scene sketch. Once the sample has been placed in the container, another photograph should be taken showing both the area from which the sample was removed and the sample inside the container.

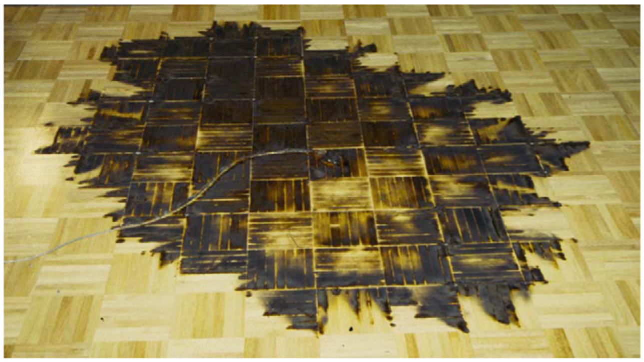

Fig. 2 Burning in the cracks of an oak parquet floor.

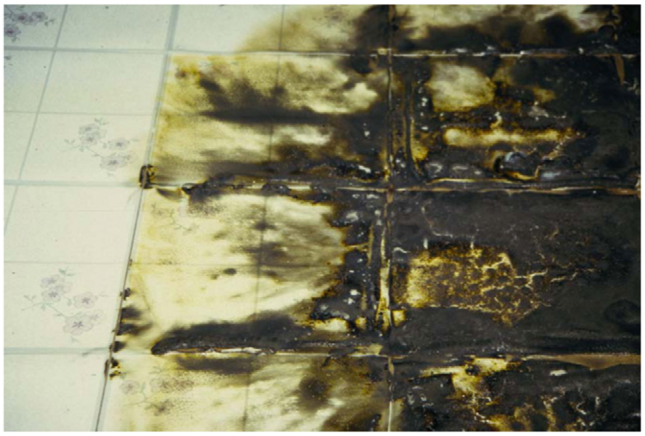

Fig. 3 Burning in the cracks of a vinyl floor.

Disposable latex or nitrile gloves should be used to collect the samples and a new pair of gloves should be used for each sample. The use of gloves should be documented, preferably with a photograph of the discarded gloves at each sample location. Gloves should not be placed in the sample container.

Random sampling is not advisable. There should be a logical reason for the collection of samples. At times, this may mean nothing more than finding the location of doorways and hallways in a structure that has burned to completion.

Plastics and synthetic fibers, because of the way they respond to heat, tend to trap ILR in the melted polymer matrix. Wood flooring also tends to hold onto ILR by adsorbing the residues on the charcoal that is produced as wood burns.

Soils can retain some ILRs, particularly heavy petroleum distillates, almost indefinitely, but some residues in soils are subject to microbial degradation. Soil samples should be refrigerated if there is any significant delay (more than a few days) between collection and submission to the laboratory, or between submission and analysis. Concrete has been known to retain detectable quantities of ILR, but the overlying floor covering (if any) is more easily sampled.

In addition to their own olfactory senses, the investigators may employ a hydrocarbon sniffer, a mechanical device that senses hydrocarbons in the air. These devices are not very selective, however, and should not be used in place of laboratory analysis. False positives are common.

An "ignitable liquid detection canine" (formerly known as an "accelerant detection canine") is probably the most effective aid to collecting samples that have a higher probability of testing positive in a laboratory. As with any tool, canines are subject to limitations. The canine responds to scents that it has previously been rewarded for alerting to. If, on a particular scene, a canine responds to pyrolysis products, rather than foreign ignitable liquids, it is likely to respond inappropriately for the rest of the day because it has been rewarded for doing so.

Canines are incapable of identifying different ILRs. This can only be determined by laboratory analysis. There are some investigators who insist that because their canine has demonstrated extreme sensitivity, a negative laboratory test of the sample selected by the canine can be ignored. This is not true. It is the considered opinion of the scientific community (including responsible canine handlers) that canine alerts unconfirmed by laboratory analysis do not constitute valid evidence of the presence of an ILR. Some canines have confirmation rates over 90%, but others fall below 50% on a regular basis. The canine is only a tool. The latest edition of NFPA 921 states, "Any canine alert not confirmed by laboratory analysis should not be considered validated and, accordingly, should not be offered as direct or circumstantial evidence of the presence of an ignitible liquid in a criminal or civil trial.

Table 1 Sources of "background" ignitable liquids

Substance	*Potential source*
Toluene, xylenes, C_3- and C_4-alkylbenzenes, indenes	Adhesives, polymer decomposition, shoes, clothing
Medium petroleum distillates and heavy petroleum distillates	Adhesives, insecticides, polishes, lubricants, magazines, newsprint, shoes, clothing, asphalt smoke, plasticizers, floor finishes
Isoparaffins	Moisture barriers, adhesives, plasticizers
Normal paraffins	Vinyl flooring, carbonless forms, copier and laser printer toner
Alcohols, acetone	Combustion products

One useful attribute of this tool is that the animal is willing to spend all day sniffing out a large area, something that most fire investigators are unwilling to attempt. If the scene has been properly cleared prior to the canine's arrival and there is any ILR to be found, the canine will likely find it.

Comparison Samples

Beginning in the 1980s, forensic science laboratories acquired the ability to detect smaller and smaller quantities of ILRs. The lower limit of detection dropped by at least two orders of magnitude. The result of this improved technology has been that the laboratory can now detect "background levels" of ILR that are normal to the area being sampled. Table 1 provides a list of common background materials that may be the source of ILRs. For example, the solvents used in hardwood floor-finishing products persist indefinitely in the thin polyurethane or other polymer film. For this reason, comparison samples are often necessary.

Because the fire investigator usually gets only one chance to sample the scene, comparison samples should be collected as a matter of routine. The samples should consist of the same substrates, such as carpet, flooring, concrete, as the suspect samples. Obviously, the comparison samples should be collected from areas where, in the fire investigator's judgment, no ignitable liquid would be expected. Except in cases where there is a large excess of ILR present on the sample, the absence of a comparison sample may render a positive finding from the laboratory invalid.

Packaging Options

Fire debris samples are typically packaged in metal cans, glass jars, or plastic evidence bags specifically designed for fire debris. Each type of packaging has advantages and disadvantages.

Metal cans are usually impervious to hydrocarbon residues, are commonly available, and resist breaking. Laboratory analysts sometimes prefer cans because the cans can be heated directly in the oven. One problem with cans is that they tend to corrode over time. Fire debris tends to contain water and acids that can cause perforation of an uncoated metal can in a matter of weeks. For this reason, lined cans, the type used for water-based paints, are recommended over unlined cans. Each time an investigator purchases a new batch of cans, an empty can should be submitted to the laboratory to verify that the can lining is not contributing significantly to the extract.

Glass jars, such as Mason jars, do not corrode, but they require careful packaging to avoid breakage and the cross contamination that may result. The two-piece lids on Mason jars were not designed for hydrocarbons, and the gasket can deteriorate if exposed to high concentrations of ILR. It is recommended that the gasket be turned away from the sample.

Two-layer nylon/polyacrylonitrile-co-methacrylate-cobutadiene bags, specifically designed for fire debris analysis, are available and have been shown to make excellent containers for fire debris, assuming they are properly sealed. Research published by Grutters et al. in 2012 has shown these bags to be superior to nylon or polyester bags that have been used for evidence collection. The evidence bags can withstand extraction oven temperatures of up to 70°C. The bags have the disadvantage of being subject to punctures, and fire debris often contains materials capable of causing a puncture.

However it is packaged, the fire debris should be labeled in accordance with industry practices. The label should include a unique identifier that allows a chain of custody to be established. A label on a fire debris sample should also include an identification of the person who collected it, the date it was collected, a brief description of the substrate, and a brief description of the location of the sample. More elaborate descriptions of the sample can be provided on an evidence transmittal, such as the one shown in Fig. 4.

Clothing and Shoes

Occasionally, law enforcement officers encounter a suspect shortly after a fire has been set and collect the suspect's clothing and shoes for ILR analysis. This can be a very useful means of linking a suspect to a fire scene, assuming it is done properly.

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EVIDENCE TRANSMITTAL

Date:________________________ Verbal Report To: ________________

Phone #: ____________________

Submitted By:____________________ Written Report To:________________

____________________ ________________________

____________________ ________________________

File #:________________________ Invoice To:____________________

Insured:________________________ ________________________

Claim Number:____________________ ________________________

Date of Loss:____________________ ________________________

ATS Reference #__________________ ________________________

Description of Evidence: Container, Size Type of Material, Condition of Material (burned or unburned) **Location Collected**

1.________________________ ________________________

2.________________________ ________________________

3.________________________ ________________________

4.________________________ ________________________

5.________________________ ________________________

Special Instructions:____

Chain of Evidence
(Signature Required)

From:________________To:________________Date:__________Time:______

From:________________To:________________Date:__________Time:______

From:________________To:________________Date:__________Time:______

Fire Investigation, Analysis and Review
Fellow, ASTM International, Fellow, American Academy of Forensic Sciences,
Member, NFPA Technical Committee on Fire Investigator Professional Qualifications,
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Fig. 4 A typical chain of custody form for submission of fire debris samples to a private laboratory.

Clothing and shoes should be packaged separately to avoid contamination of the clothing with the background compounds on the shoes.

The left and right shoes should likewise be packaged separately. Shoes often contain significant quantities of ILRs because of the dyes and adhesives used in their manufacture. If an accelerant is splashed on an arsonist's shoes, it is unlikely that each shoe will be contaminated with the same amount. Thus, one shoe could act as a comparison sample for the other. It may be necessary to try to find a new pair of shoes of the same manufacture as the suspect's shoes, in order to determine what should and should not be present on the shoes.

Liquids for Comparison

Fire investigators will sometimes find containers of ignitable liquids at fire scenes that they wish to submit for comparison with residues extracted from test samples. This can be accomplished, but it is necessary to take affirmative steps to avoid contaminating the test samples with the comparison liquids. The liquid should be packaged and shipped separately from the test samples. Suitable containers for liquids include flint glass jars, or small evidence cans containing surgical gauze pads onto which a liquid is absorbed. Note that "nonstick" gauze pads may contain petroleum products and are not suitable for absorbing liquids.

There are times when liquid absorbed onto a gauze pad is not suitable. Sometimes it is necessary to conduct a flash point test to determine whether a liquid meets statutory requirements. For example, some jurisdictions define a Molotov cocktail as a breakable container filled with a flammable liquid. In such a case, a sample of at least 5 ml of liquid is required and preferably 100 ml.

The laboratory procedures necessary to "match" an ignitable liquid to a particular source are beyond the scope of this article, but readers should be aware that, except in the most unusual cases, the laboratory will only be capable of excluding a particular source, rather than positively identifying the comparison liquid as the source of the residue found on the test samples.

Evidence Collection for Other Types of Testing

Spontaneous Heating

The forensic science laboratory can perform other chemical and physical analyses in addition to testing for ILR.

Oily rags, suspected of having undergone spontaneous ignition, are collected and packaged in the same way as fire debris submitted for ILR analysis. The investigator needs to tell the laboratory that spontaneous heating is suspected because the analytical procedure for finding the kinds of products that undergo spontaneous heating (usually vegetable oils) is different from the procedure used for detecting ILR. It is possible to conduct the testing for vegetable oils on the same sample used to test for ILR. ILR can be isolated using a nondestructive headspace concentration technique, and then the vegetable oils can be extracted with a solvent.

Occupancies that are subject to fires caused by spontaneous heating include commercial laundries, restaurants, and health spas, as well as buildings under construction or renovation where oil-based paints and stains are used. Spontaneous heating fires tend to occur in clothes dryers when the laundry has not been thoroughly cleansed of vegetable oils. These fires happen after the dryer has stopped, and sometimes after the laundry has been removed and stacked. Spontaneous fires associated with painting typically occur as a result of improper disposal of rags or filters contaminated with products that contain linseed or tung oil.

Laboratory analysis for vegetable oils can only determine whether the oils are present. The laboratory analysis will not allow a determination that the oils actually underwent spontaneous heating or combustion.

Electrical Malfunctions

Most public-sector forensic science laboratories do not have in-house capabilities for examining appliances or other electrical devices suspected of causing a fire. An engineering laboratory will usually be required for such analyses.

If a product malfunction is suspected, the fire investigator is advised to ensure that any entity that might be a party to litigation has the opportunity to participate in the inspection. When possible, this should include making any suspect device available both on the fire scene and in the engineering laboratory.

The appliance or device should be fully documented on the scene and then labeled to provide a chain of custody. If there are exemplars of appliances at the fire scene, they should be collected as well. Additionally, appliances in the general area of origin, which the investigator does not believe started the fire, should be collected for purposes of elimination. Appliances and devices damaged in fires are typically delicate. Conductors and other parts may have melted or become brittle. Care should be taken to avoid further damage in the packaging and transportation of damaged appliances to the laboratory.

Laboratory inspection will usually involve the use of a magnifying glass or a stereomicroscope. X-ray examination is desirable prior to performing any destructive disassembly of the appliance or device. Real-time x-ray is usually preferable to examination with industrial x-rays and film because it can be accomplished in a more reasonable time frame.

An experienced fire investigator or electrical engineer can usually recognize evidence of electrical activity. The hallmarks of electrical activity are that the damage to the conductor is highly localized and complementary, that is, one can identify both the high-voltage and low- (or zero) voltage side of the arcing event. On small-diameter stranded wires, such as low-amperage appliance power cords, it is possible to become confused between environmental melting and electrical melting. Scanning electron microscopy is often useful, especially when different metals were involved in the arcing event.

Except in cases where a loose connection results in "series arcing", electrical arcs are almost always a result of an energized conductor being exposed to the fire. The insulation on the conductor carbonizes and becomes conductive, resulting in "arcing through char". Such arcing may help to pinpoint the origin of the fire, but it is always a result of the fire.

There is currently no valid laboratory analysis that can identify an arc that caused a fire. Scanning electron microscopy and auger electron microscopy have both been tried, but neither is accepted as valid for making the identification of an electrical arc that started a fire. An arc is a very short-lived event and is incapable of igniting most fuels. Only gases, dusts, and very lightweight fuels can be ignited by an arc. See NFPA 921 at §9.9.4.

Heat-producing devices are typically equipped with safety features that, surprisingly, may survive a fire in testable form. This is because the devices are designed to withstand a hot environment. One-time fuses can be tested to see if they are electrically open. Resettable bimetallic thermal cutoff devices can be examined to see if they are open or closed, and they can be heated with a hair dryer to determine whether they still respond to heat.

Some metals respond to heating by undergoing microscopic changes in their grain structure. These changes are capable of being identified by a metallurgist. The testing required to visualize the grain structure involves cutting and polishing a section of the metal, so appropriate steps regarding destructive testing need to be taken.

Other Forensic Analyses

Because of the destructive nature of fires, investigators often overlook traditional forensic evidence such as fingerprints, blood, toolmarks, and other kinds of trace evidence. Much of this evidence can survive the fire, and particularly in incendiary fires, is capable of associating a suspect with the scene.

In fatal fires, the body constitutes significant evidence. A toxicological evaluation of the victim's blood can determine whether the victim was alive during the fire. A victim with no carbon monoxide in his or her blood was probably dead before the fire began. Research published by McAllister et al. in 2013 has indicated that there is a relationship between carbon monoxide levels and the victim's location relative to the origin of the fire. Victims who die from thermal injuries because they were close to the origin typically have lower carbon monoxide levels than victims found in rooms some distance from the origin, particularly when the room of origin progressed beyond flashover. Because flashover consumes most to the oxygen in a room, the smoke exhausted from that room tends to contain high concentrations of carbon monoxide.

Conclusions

Accurate determination of the cause of a fire is a discipline with very high stakes. The primary goal of the investigator, particularly in the public sector, is determining whether a crime has been committed. This requires a detailed knowledge of fire behavior, beyond what is learned in fighting fires and beyond the simple concept that heat rises.

Fire scenes are dangerous places that pose the risk of immediate physical harm and long-term harm from breathing the contaminant-filled air at the scene. Situational awareness is important, and safety is paramount.

Collecting evidence at a fire scene requires following the usual rules for collecting evidence, but also understanding what happens in the laboratory, and how to avoid mistaking innocent background components for evidence of accelerants.

Further Reading

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http://www.NFPA.org
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