THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF HOME AFFAIRS

FIRE AND RESCUE FORCE

STANDARD OPERATING PROCEDURE MANUAL

Second Edition

VOLUME IX

FIRE INCIDENT INVESTIGATION

2025

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CHAPTER ONE

1.0. INTRODUCTION

This document is designed to assist individuals who are charged with the responsibility of investigating and analyzing fire and explosion incidents and rendering opinions as to the origin, cause, responsibility, or prevention of such incidents and the damage and injuries that arise from such incidents.

1.1. Purpose

The purpose of this document is to establish guidelines and recommendations for the safe and systematic investigation or analysis of fire and explosion incidents. Fire investigation or analysis and the accurate listing of causes are fundamental to the protection of lives and property from the threat of hostile fire or explosions. It is through an efficient and accurate determination of the cause and responsibility that future fire incidents can be avoided. This document has been developed as a model for the advancement and practice of fire and explosion investigation, fire science, technology, and methodology.

Proper determination of fire origin and cause, as well as the cause of and responsibility for property damage, injuries, or deaths, is also essential for the meaningful compilation of fire statistics. Accurate statistics form part of the basis of fire prevention codes, standards, and training.

1.2. Application

This document is designed to produce a systematic, working framework or outline by which effective fire and explosion investigation and origin and because analysis can be accomplished. It contains specific procedures to assist in the investigation of fires and explosions. These procedures represent the judgment developed from the NFPA consensus process system that if followed can improve the probability of reaching sound conclusions. Deviations from these procedures, however, are not necessarily wrong or inferior but need to be justified.

The reader should note that frequently the phrase *fire investigation* is used in this document when the context indicates that the relevant text refers to the investigation of both fires and explosions.

As every fire and explosion incident is in some way unique and different from any other, this document is not designed to encompass all the necessary components of a complete investigation or analysis of any one case. The scientific method, however, should be applied in every instance.

Not every portion of this document may be applicable to every fire or explosion incident. It is up to investigators (depending on their responsibility, as well as the purpose and scope of their investigation) to apply the appropriate recommended procedures in this guide to a particular incident.

In addition, it is recognized that the extent of the fire investigator's assignment, time and resource limitations, or existing policies may limit the degree to which the recommendations or techniques in this document will be applied in a given investigation.

This document is not intended as a comprehensive scientific or engineering text. Although many scientific and engineering concepts are presented within the text, the user is cautioned that additional technical resources, training, and education may often need to be utilized in an investigation.

1.3. Units of Measure

Metric units of measurement in this guide are in accordance with the modernized metric system known as the International System of Units (SI). The unit of liter is outside of but recognized by SI and is commonly used in international firefighting procedures.

1.4. Measurement Uncertainty

The precision and accuracy of measurements reported in this guide may be relatively high, such as density measurements of pure substances, or more variable, such as gas temperatures, heat release rates, or event times in test fires. Therefore, all reported measurements or factors in equations should be evaluated to assess whether the level of precision and accuracy expressed is appropriate or broadly applicable.

CHAPTER TWO

2.0. BASIC METHODOLOGY

2.1. Nature of Fire Investigations

A fire or explosion investigation is a complex endeavor involving skill, technology, knowledge, and science. The compilation of factual data, as well as an analysis of those facts, should be accomplished objectively, truthfully, and without expectation bias, preconception, or prejudice. The basic methodology of the fire investigation should rely on the use of a systematic approach and attention to all relevant details. The use of a systematic approach often will uncover new factual data for analysis, which may require previous conclusions to be reevaluated.

2.2. Systematic Approach

The systematic approach recommended is based on the scientific method, which is used in the physical sciences. This method provides an organizational and analytical process that is desirable and necessary in a successful fire investigation.

2.3. Relating Fire Investigation to the Scientific Method

The scientific method is a principle of inquiry that forms a basis for legitimate scientific and engineering processes, including fire incident investigation. It is applied using the steps outlined in the figure below: -

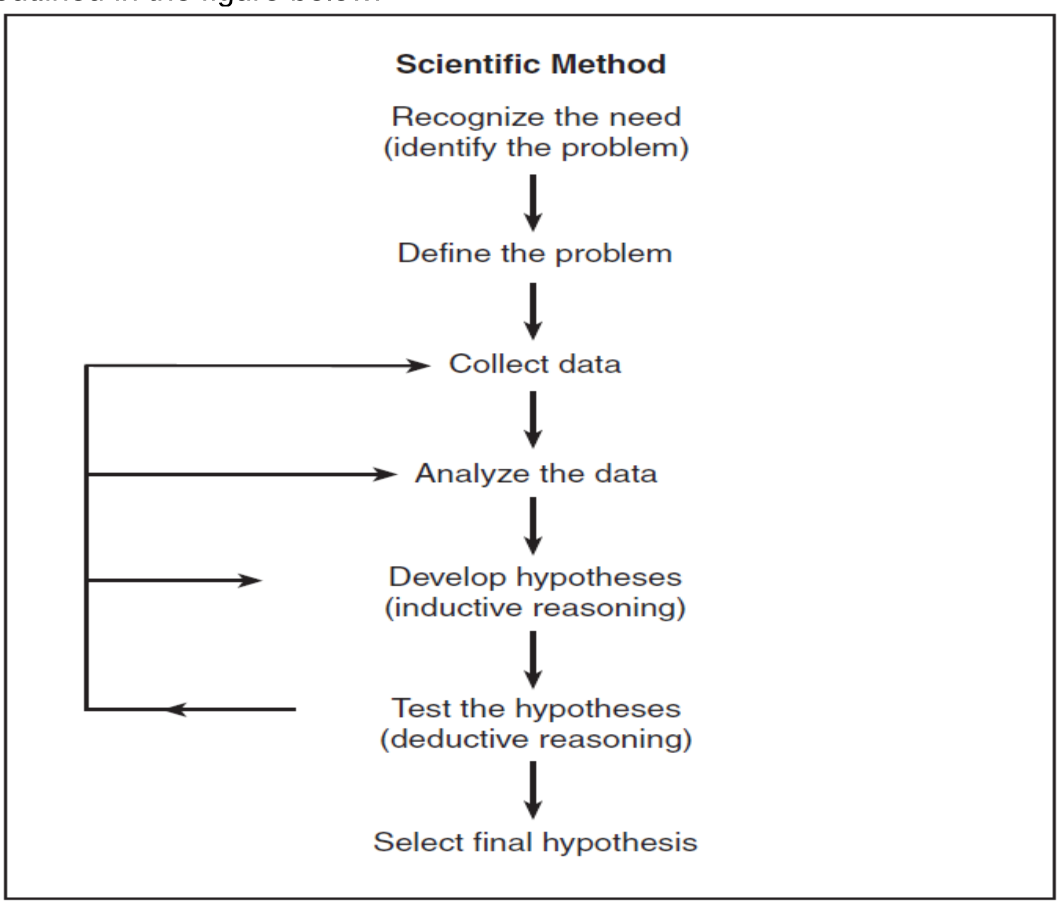


Figure 1: The Scientific Method

2.3.1. Recognize the Need

First, one should determine that a problem exists. In this case, a fire or explosion has occurred and the cause should be determined and listed so that future, similar incidents can be prevented.

2.3.2. Define the Problem

Having determined that a problem exists, the investigator or analyst should define the manner in which the problem can be solved. In this case, a proper origin and cause investigation should be conducted. This is done by an examination of the scene and by a combination of other data collection methods, such as the review of previously conducted investigations of the incident, the interviewing of witnesses or other knowledgeable persons, and the results of scientific testing.

2.3.3. Collect Data

Information about the fire or explosion incident is now collected by observation, experiment, or other direct data-gathering means. The data collected is called empirical data because it is based on observation or experience and is capable of being verified or known to be true.

2.3.4. Analyze the Data

The scientific method requires that all data collected be analyzed. This is an essential step that must take place before the formation of the final hypothesis. The identification, gathering, and cataloging of data does not equate to data analysis. Analysis of the data is based on the knowledge, training, experience, and expertise of the individual doing the analysis. If the investigator lacks expertise to properly attribute meaning to a piece of data, then assistance should be sought. Understanding the meaning of the data will enable the investigator to form hypotheses based on the evidence, rather than on speculation.

2.3.5. Develop Hypotheses (Inductive Reasoning)

Based on the data analysis, the investigator produces hypotheses to explain the phenomena, whether it be the nature of fire patterns, fire spread, identification of the origin, the ignition sequence, the fire cause, or the causes of damage or responsibility for the fire or explosion incident.

This process is referred to as inductive reasoning. 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.

2.3.6. Test the Hypotheses (Deductive Reasoning)

The investigator does not have a valid or reliable conclusion unless the hypothesis can stand the test of careful and serious challenge. Testing of the hypothesis is done by the principle of deductive reasoning, in which the investigator compares the hypothesis to all known facts as well as the body of scientific knowledge associated with the phenomena relevant to the specific incident.

Testing of a hypothesis should be designed to disprove, or refute, the hypothesis. This may also be referred to as falsification of the hypothesis. Working to disprove a hypothesis is an attempt to find all the data or reasons why the hypothesis is not supported or not true, rather than simply finding and relying on data that support the hypothesis or why the hypothesis is true. This method of testing the hypothesis can prevent “confirmation bias,” which can occur when the hypothesis or conclusion relies only on supporting data.

A hypothesis can be tested physically by conducting experiments, analytically by applying accepted scientific principles, or by referring to scientific research. When relying on the research of others, the investigator or analyst must ensure that the conditions, circumstances, and variables of the research and those of the hypothesis are sufficiently similar. Whenever the investigator relies on research as a means of hypothesis testing, references to the research relied upon should be acknowledged and cited.

If the hypothesis is refuted or not supported, it should be discarded and alternate hypotheses should be developed and tested. This may require the collection of new data or the reanalysis of existing data. 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. If no hypothesis can withstand an examination by deductive reasoning, the issue should be considered undetermined.

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.

2.3.7. Select Final Hypothesis

The final step in applying the scientific method is to select the final hypothesis. Once the hypothesis has been tested, the investigator should review the entire process to ensure that all credible data are accounted for and all feasible alternate hypotheses have been considered and eliminated.

When using the scientific method, the failure to consider alternate hypotheses is a serious error. A critical question to be answered is, **"Are there any other hypotheses that are consistent with the data?"** The investigator should document the facts that support the final hypothesis to the exclusion of all other reasonable hypotheses.

2.3.8. Avoid Presumption

Until data have been collected, no specific hypothesis can be reasonably formed or tested. All investigations of fire and explosion incidents should be approached by the investigator without presumption as to origin, ignition sequence, cause, fire spread, or responsibility for the incident until the use of the scientific method has yielded testable hypotheses, which cannot be disproved by rigorous testing.

2.3.9. Expectation Bias

Expectation bias is a well-established phenomenon that occurs in scientific analysis when investigator(s) reach a premature conclusion without having examined or considered all of the relevant data. Instead of collecting and examining all of the data in a logical and unbiased manner to reach a scientifically reliable conclusion, the investigator(s) uses the premature determination to dictate investigative processes, analyses, and, ultimately, conclusions, in a way that is not scientifically valid.

The introduction of expectation bias into the investigation results in the use of only that data that supports this previously formed conclusion and often results in the misinterpretation and/or the discarding of data that does not support the original opinion. Investigators are strongly cautioned to avoid expectation bias through proper use of the scientific method.

2.3.10. Confirmation Bias

Different hypotheses may be compatible with the same data. When using the scientific method, testing of hypotheses should be designed to disprove a hypothesis (i.e., falsification of the hypothesis), rather than relying only on confirming data that support the hypothesis. Confirmation bias occurs when the investigator relies exclusively on data that supports the hypothesis and fails to look for, ignores, or dismisses contradictory or no supporting data. The same data may support alternate and even opposing hypotheses.

The failure to consider alternate or opposing hypotheses, or prematurely discounting seemingly contradictory data without appropriate analysis and testing can result in incorrect conclusions. A hypothesis can be said to be valid only when rigorous testing has failed to disprove the hypothesis. Disproving the hypothesis is a process in which all the evidence is compared against the proffered hypothesis in an effort to find why the hypothesis is not true.

2.4. Basic Method of a Fire Investigation

Using the scientific method in most fire or explosion incidents should involve the following steps: -

2.4.1. Receiving the Assignment

The investigator should be notified of the incident, told what his or her role will be, and told what he or she is to accomplish. For example, the investigator should know if he or she is expected to determine the origin, cause, and responsibility; produce a written or oral report; prepare for criminal or civil litigation; make suggestions for code enforcement, code promulgation, or changes; make suggestions to manufacturers, industry associations, or government agency action; or determine some other results.

2.4.2. Preparing for the Investigation

The investigator should marshal his or her forces and resources and plan the conduct of the investigation. Preplanning at this stage can greatly increase the efficiency and therefore the chances for success of the overall investigation. Estimating what tools, equipment, and personnel (both laborers and experts) will be needed can make the initial scene investigation, as well as subsequent investigative examinations and analyses, go more smoothly and be more productive.

2.4.3. Conducting the Investigation

It is during this stage of the investigation that an examination of the incident fire or explosion scene is conducted. The fundamental purpose of conducting an examination of any incident scene is to collect all of the available data and document the incident scene. The investigator should conduct an examination of the scene if it is available and collect data necessary to the analysis.

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.

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. Thus, the reliance on previously collected data and scene documentation should not be inherently considered a limitation in the ability to successfully investigate the incident.

The goal of all investigators is to arrive at accurate determinations related to the origin, cause, fire spread, and responsibility for the incident. 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.

2.4.4. Collecting and Preserving Evidence

Valuable physical evidence should be recognized, documented, properly collected, and preserved for further testing and evaluation or courtroom presentation.

2.4.5. Analyzing the Incident

All collected and available data should be analyzed using the principles of the scientific method. Depending on the nature and scope of one’s assignment, hypotheses should be developed and tested explaining the origin, ignition sequence, fire spread, fire cause or causes of damage or casualties, or responsibility for the incident.

2.4.6. Conclusions

Conclusions, which are final hypotheses, are drawn as a result of testing the hypotheses. Conclusions should be drawn according to the principles expressed in this guide and reported appropriately.

2.5. Level of Certainty

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.

The investigator should know the level of certainty that is required for providing expert opinions. Two levels of certainty commonly used are probable and possible:

a) Probable

This level of certainty corresponds to being more likely true than not. At this level of certainty, the likelihood of the hypothesis being true is greater than 50 percent.

a) Possible

At this level of certainty, the hypothesis can be demonstrated to be feasible but cannot be declared probable. If two or more hypotheses are equally likely, then the level of certainty must be “possible.”

If the level of certainty of an opinion is merely “suspected,” the opinion does not qualify as an expert opinion. If the level of certainty is only “possible,” the opinion should be specifically expressed as “possible.” Only when the level of certainty is considered “probable” should an opinion be expressed with reasonable certainty.

2.6. Expert Opinions

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 “reasonable degree of certainty within my profession.” While these terms of art may be important for the specific jurisdiction or court in which they apply, defining these terms in those contexts is beyond the scope of this document.

2.7. Review Procedure

A review of a fire investigator’s work product (e.g., reports, documentation, notes, diagrams, photos, etc.) by other persons may be helpful, but there are certain limitations. This section describes the types of reviews and their appropriate uses and limitations.

2.7.1. Administrative Review

An administrative review is one typically carried out within an organization to ensure that the investigator’s work product meets the organization's quality assurance requirements. An administrative reviewer will determine whether all of the steps outlined in an organization's procedure manual, or required by agency policy, have been followed and whether all of the appropriate documentation is present in the file, and may check for typographical or grammatical errors.

2.7.1.1. Limitations of Administrative Reviews

An administrative reviewer may not necessarily possess all of the knowledge, skills, and abilities of the investigator or of a technical reviewer. As such, the administrative reviewer may not be able to provide a substantive critique of the investigator's work product.

2.7.2. Technical Review

A technical review can have multiple facets. If a technical reviewer has been asked to critique all aspects of the investigator's work product, then the technical reviewer should be qualified and familiar with all aspects of proper fire investigation and should, at a minimum, have access to all of the documentation available to the investigator whose work is being reviewed. If a technical reviewer has been asked to critique only specific aspects of the investigator's work product, then the technical reviewer should be qualified and familiar with those specific aspects and, at a minimum, have access to all documentation relevant to those aspects. A technical review can serve as an additional test of the various aspects of the investigator's work product.

2.7.2.1. Limitations of Technical Reviews

While a technical review may add significant value to an investigation, technical reviewers may be perceived as having an interest in the outcome of the review. Confirmation bias (attempting to confirm a hypothesis rather than attempting to disprove it) is a subset of expectation bias, this kind of bias can be introduced in the context of working relationships or friendships. Investigators who are asked to review a colleague's findings should strive to maintain a level of professional detachment.

2.7.3. Peer Review

Peer review is a formal procedure generally employed in prepublication review of scientific or technical documents and screening of grant applications by research-sponsoring agencies. Peer review carries with it connotations of both independence and objectivity. Peer reviewers should not have any interest in the outcome of the review.

The author does not select the reviewers, and reviews are often conducted anonymously. As such, the term "peer review" should not be applied to reviews of an investigator's work by coworkers, supervisors, or investigators from agencies conducting investigations of the same incident. Such reviews are more appropriately characterized as "technical reviews," as described above.

2.7.3.1. Limitations of Peer Reviews

Peer reviewers should have the expertise to detect logic flaws and inappropriate applications of methodology or scientific principles, but because they generally have no basis to question an investigator's data, they are unlikely to be able to detect factual errors or incorrectly reported data. Conclusions based on incorrect data are likely to be incorrect themselves. Because of these limitations, a proper technical review will provide the best means to adequately assess the validity of the investigation's results.

2.8. Reporting Procedure

The reporting procedure may take many written or oral forms, depending on the specific responsibility of the investigator. Pertinent information should be reported in a proper form and forum to help prevent recurrence.

CHAPTER THREE

PLANNING THE INVESTIGATION

3.0. Introduction

Regardless of the number of people involved, the need to preplan investigations remains constant. Considerations for determining the number of investigators assigned include budgetary constraints, available staffing, complexity, loss of life, and size of the scene to be investigated.

The person responsible for the investigation of the incident should identify the resources at his or her disposal and those available from outside sources before those resources are needed.

3.1. Basic Incident Information

Prior to beginning the incident scene investigation, numerous events, facts, and circumstances should be identified. Accuracy is important, because a mistake at this point could jeopardize the subsequent investigation results.

3.1.1. Location

The investigator, once notified of an incident, should obtain as much background information as possible relative to the incident from the requester. If the travel distance is great, arrangements may be required to transport the investigation team to the incident scene. The location of the incident may also dictate the need for specialized equipment and facilities.

3.1.2. Date and Time of Incident

The investigator should accurately determine the day, date, and time of the incident. The age of the scene may have an effect on the planning of the investigation. The greater the delay between the incident and the investigation, the more important it becomes to review pre-existing documentation and information such as incident reports, photographs, building plans, and diagrams.

3.1.3. Weather Conditions

Weather at the time of the investigation may necessitate special clothing and equipment. Weather may also determine the amount of time the team members can work an incident scene. Extreme weather may require that greater safety precautions be taken on behalf of the team members, for example, when the weight of snow on a structure weakens it. Weather conditions such as wind direction and velocity, temperature, and rain during a fire should be noted because all can have an effect on the ignition and fire spread.

3.1.4. Size and Complexity of Incident

The size and complexity of the scene will also affect the length of the investigation, and preparations may be needed for housing and feeding the team members. Generally, the larger the incident scene, the greater the length of time required to conduct the investigation.

3.1.5. Type and Use of Structure

The investigator should identify the type and use of the incident structure. The use or occupancy of the structure (e.g., industrial plant, chemical processing plant, storage warehouse, nuclear facility, or radiological waste storage) may necessitate special containment of debris, contamination, or radiation, including water runoff at the scene.

Knowledge of the type of construction and construction materials will provide the investigator with valuable background information and allow anticipation of circumstances and problems to be encountered by the investigation team.

3.1.6. Nature and Extent of Damage

Information on the condition of the scene may alert the investigator to special requirements for the investigation, such as utility testing equipment, specialized expertise, additional staffing, and special safety equipment. The investigator may be operating under time constraints and should plan accordingly.

The investigator should ensure that initiation of the investigation will not be contrary to post-incident orders issued by local, state, or federal regulatory agencies. Issues that often lead to such orders may involve structural stability and the presence of hazardous materials.

3.1.7. Security of Scene

The investigator should promptly determine the identity of the individual, authority, or entity that has possession or control of the scene. Right of access and means of access should be established. Scene security is a consideration. If possible, arrangements should be made to preserve the scene until the arrival of the investigator(s). If this is not possible, arrangements should be made to photograph and document existing conditions prior to disturbance or demolition.

3.1.8. Purpose of Investigation

While planning the investigation, the investigator should remain aware of his or her role, the scope of the investigation, and areas of responsibility. Numerous investigators may be involved, from both the private and public sectors. Mutual respect and cooperation in the investigation is required.

The investigator, the private-sector investigator in particular, should recommend to the client that they need to notify all identifiable interested parties who may have a legal interest in the investigation of the inspection and give them the opportunity to participate or witness and record such activities.

3.2. Organizing the Investigation Functions

There are basic functions that are commonly performed in each investigation. These are the leadership/coordinating function; photography, note taking, mapping, and diagramming, interviewing witnesses, searching the scene, evidence collection and preservation; and safety assessment.

In addition, specialized expertise in such fields as electrical, heating and air conditioning, or other engineering fields is often needed. The investigator should, if possible, fulfill these functions with the personnel available. In assigning functions, those special talents or training that individual members possess should be utilized.

3.3. Pre-Investigation Team Meeting

If the investigator has established a team, a meeting should take place prior to the on-scene investigation. The team leader or investigator should address questions of jurisdictional boundaries and assign specific responsibilities to the team members.

Personnel should be advised of the condition of the scene and the safety precautions required.

3.4. Equipment and Facilities

Each person on the fire scene should be equipped with appropriate safety equipment, as required. A complement of basic tools should also be available. The tools and equipment listed may not be needed on every scene, but in planning the investigation, the investigator should know where to obtain these tools and equipment if the investigator does not carry them.

3.5. Personal Safety Equipment

Recommended personal safety equipment includes the following:
Eye protection

i. Flashlight
ii. Gloves
iii. Helmet or hard hat
iv. Respiratory protection (type depending on exposure)
v. Safety boots or shoes
vi. Turnout gear or coveralls

3.6. Tools and Equipment

Recommended tools and equipment include the following:

i. Absorption material
ii. Air blaster (found in camera stores)
iii. Axe
iv. Batteries
v. Broom
vi. Calcination Gauge
vii. Camera and film
viii. Char gauge/Digital caliper
ix. Claw hammer
x. Directional compass
xi. Evidence-collecting container
xii. Evidence labels (sticky)
xiii. Hand towels
xiv. Hatchet
xv. Hydrocarbon detector
xvi. Ladder

xvii. Lighting
xviii. Magnet
xix. Marking pens
xx. Metal detector/Probe
xxi. Paint brushes
xxii. Paper towels/wiping cloths
xxiii. Pen knife
xxiv. Pliers/wire cutters
xxv. Pry bar
xxvi. Rake
xxvii. Rope
xxviii. Ruler/Straight edge
xxix. Saw
xxx. Screwdrivers (multiple types)
xxxi. Shovel
xxxii. Sieve/Shifting screens
xxxiii. Soap and hand cleaner or moist towelettes
xxxiv. Styrofoam cups
xxxv. Tape measure
xxxvi. Tape recorder
xxxvii. Tongs
xxxviii. Tweezers
xxxix. Twine
xl. Voltage detector (Pen shaped device to show live circuits)
xli. Voltmeter/ohmmeter
xlii. Water
xliii. Writing/drawing equipment

3.7. Specialized Personnel and Technical Consultants.

During the planning of a fire investigation, specialized personnel may be needed to provide technical assistance. There are many different facets to fire investigation. If unfamiliar with a particular aspect, the investigator should never hesitate to call in another fire investigative expert who has more knowledge or experience in a particular aspect of the investigation. For example, there are some experts who specialize in explosions.

Sources for these specialized personnel/experts include colleges or universities, government agencies (federal, state, and local), societies or trade groups, consulting firms, and others. When specialized personnel are brought in, it is important to remember that conflict of interest should be avoided. Identification of special personnel in advance is recommended.

It should be kept in mind that fire investigation is a specialized field. These specialized personnel are such as:

3.7.1. Materials Engineer or Scientist

A person in this field can provide specialized knowledge about how materials react to different conditions, including heat and fire. In the case of metals, someone with a metallurgical background may be able to answer questions about corrosion, stress, failure or fatigue, heating, or melting.

3.7.2. Mechanical Engineer

A mechanical engineer may be needed to analyze complex mechanical systems or equipment, including heating, ventilation, and air-conditioning (HVAC) systems, especially how these systems may have affected the movement of smoke within a building. The mechanical engineer may also be able to perform strength-of-material tests.

3.7.3. Electrical Engineer

An electrical engineer may provide information regarding building fire alarm systems, energy systems, power supplies, or other electrical systems or components. An electrical engineer may assist by quantifying the normal operating parameters of a particular system and determining failure modes.

3.7.4. Chemical Engineer/Chemist

A chemical engineer has education in chemical processes, fluid dynamics, and heat transfer. When a fire involves chemicals, a chemical process, or a chemical plant, the chemical engineer may help the investigator identify and analyze possible failure modes.

3.7.5. Fire Science and Engineering

Within the field of fire science and engineering, there are a number of areas of special expertise that can provide advice and assistance to the investigator. These are:

a) Fire Protection Engineer.

b) Environmental Engineering
c) Fire Engineering Technologist.
d) Fire Engineering Technician.
e) Laboratory Technologist.

3.7.6. Industry Expert

When the investigation involves a specialized industry, piece of equipment, or processing system, an expert in that field may be needed to fully understand the processes involved. Experience with the specific fire hazards involved and the standards or regulations associated with the industry and its equipment and processes can provide valuable information to the investigator. Industry experts can be found within companies, trade groups, or associations.

3.7.7. Attorney

An attorney can provide needed legal assistance with regard to rules of evidence, search and seizure laws, gaining access to a fire scene, and obtaining court orders.

3.7.8. Insurance Agent/Adjuster

An insurance agent or adjuster may be able to provide the investigator with information concerning the building and its contents prior to the fire, fire protection systems in the building, and the condition of those systems. Additional information regarding insurance coverage and prior losses may be available.

CHAPTER FOUR

4.0. INVESTIGATION PROTOCOL

The following guidelines shall be followed by all investigators on all scenes in which an investigation is being performed.

a. All persons representing the Force in an official position shall dress appropriately and conduct themselves in a professional manner. They shall be well groomed and identifiable.

b. Routine investigations require a non-emergency response, unless directed by the Incident Commander. This will require obeying all driving laws and signals.

c. The investigator shall attempt to get information such as the incident number and related data via telephone prior to the response. If this is not possible then attempt to gather this by phone once on the scene. As a last resort this information can be requested by VHF radio from the investigator.

d. Upon arrival meet with the Incident Commander to gather any information that has already been determined. Also determine why a request for an investigator was requested (suspicious, or unable to determine).

e. Interview the first in firefighter(s) and station incharge officer for information that was encountered upon arriving. This shall be a written statement. Ask questions:
    1. Where was original fire?
    2. What was color of smoke?
    3. What was the direction of smoke travel?
    4. Were the doors locked?
    5. Was electrical power in place?
    6. Did anyone leave the scene?

f. Talk to the owner, tenant, driver, etc. to find out what they think happened. Gather the following paperwork in complete form:
    1. Consent to Search
    2. Voluntary Statements
    3. Investigation Report
    4. Individual' s Rights Form (if needed)

g. Interview any witnesses and obtain written statements.

h. Ensure that all forms are complete, dated, signed, and witnessed.

i. Begin the proper Fire Investigation Report Form and site investigation. The site investigation is to be completed as described in the rest of this section. Any Fire Investigation Report should be completed for all investigations that do not qualify as a structure or vehicle fire.

j. The Incident Commander shall call for the Police Department on all fire investigations involving fatalities.

4.1. Evidence Preservation and Custody

Evidence preservation and custody are very important aspects of a fire investigation. In order to adhere to the legal aspects of this the following guidelines are developed.

a. All samples shall be placed in a clean, unused container that can be securely closed and is suitable for the type of evidence

b. Complete the evidence label and attach to the container, place the sample in the Container and seal with security tape.

c. Samples shall be gathered by the following methods:

   1. Sample from the area of origin.
   2. Sample from an unrelated area of the same type. This will be the control sample.

d. Ensure that the proper photographs are taken before moving the items.

e. Complete the Evidence Log/Chain of Custody form.

f. Secure the samples, Evidence Log, and Chain of Custody forms in an area that can be locked (trunk of investigator's car). Do not let the chain of custody be broken.

g. Deliver the evidence to the proper lab or another person and ensure that the Chain of Custody form is signed.

4.2. Chain of Custody of Physical Evidence

The value of physical evidence entirely depends on the fire investigator's efforts to maintain the security and integrity of that physical evidence from the time of its initial discovery and collection to its subsequent examination and testing. At all times after its discovery and collection, physical evidence should be stored in a secured location that is designed and designated for this purpose. Access to this storage location should be limited in order to limit the chain of custody to as few persons as possible. Wherever possible, the desired storage location is one that is under the sole control of the fire investigator.

When it is necessary to pass chain of custody from one person to another, it should be done using a form on which the receiving person signs for the physical evidence.

4.3. Types of Evidence

There are basically three types of evidence, all of which in some manner relate to fire investigations. They are “demonstrative evidence,” “documentary evidence,” and “testimonial evidence.”

i. Demonstrative Evidence

Demonstrative evidence consists of tangible items as distinguished from testimony of witnesses about the items. It is evidence from which one can derive a relevant firsthand impression by seeing, touching, smelling, or hearing the evidence. Demonstrative evidence should be authenticated. Evidence is authenticated in one of two ways: through witness identification (i.e., recognition testimony), or by establishing a chain of custody (an unbroken chain of possession from the taking of the item from the fire scene to the exhibiting of the item).

ii. Photographs/Illustrative Forms of Evidence

Among the most frequently utilized types of illustrative demonstrative evidence are maps, sketches, diagrams, and models. They are generally admissible on the basis of testimony that they are substantially accurate representations of what the witness is endeavoring to describe. Photographs and movies are viewed as graphic portrayals of oral testimony and become admissible when a witness has testified that they are correct and accurate representations of relevant facts observed by the witness. The witness often need not be the photographer, but he or she should know about the facts being represented or the scene or objects being photographed. Once this knowledge is demonstrated by the witness, he or she can state whether a photograph correctly and accurately portrays those facts.

iii. Documentary Evidence

Documentary evidence is any evidence in written form. It may include business records such as sales receipts, inventory lists, invoices, and bank records, including checks and deposit slips; insurance policies; personal items such as diaries, calendars, and telephone records; fire department records such as the fire investigator's report, the investigator's notes, the fire incident report, and witness statements reduced to writing; or any law enforcement agency reports, including investigation reports, police officer operational reports, and fire or police department dispatcher logs; division of motor vehicle records; and written transcripts of audio- or videotape recordings. Any information in a written form related to the fire or explosion incident is considered documentary evidence. All witness statements should be properly signed by the witness, dated, and witnessed by a third party when possible. It is important to obtain the full name, address, and telephone number of the witness.

iv. Testimonial Evidence

Testimonial evidence is that given by a competent live witness speaking under oath or affirmation. Investigators are frequently called on to give testimonial evidence regarding the nature, scope, conduct, and results of their investigation. It is incumbent on all witnesses to respond completely and honestly to all questions. There are two types of witnesses that offer testimony in a legal proceeding: “fact witnesses” and “expert witnesses.”

v. Fact Witnesses

A fact witness is one whose testimony is not based on scientific, technical, or another specialized knowledge. An example of a fact witness is a neighbor who discovered the fire and testifies about their observations. An investigator will often be called to give testimony before courts, administrative bodies, regulatory agencies, and related entities as a fact witness. In addition to giving factual testimony, an investigator can be called to give conclusions or opinions regarding a fire, as an expert witness. Opinion testimony by a fact witness is allowed in limited circumstances.

4.4. Arson

Arson is the most commonly recognized fire-related crime.

4.4.1. Arson Statutes

The laws of each jurisdiction should be carefully researched regarding the requirements, burden of proof, and penalties for the crime of arson. Arson generally, or in the first and second degrees (if so classified), is deemed a felony offense. Such felony offenses require proof that the person intentionally damaged property by starting or maintaining a fire or causing an explosion. Arson in the third degree (if so classified) generally requires only reckless conduct that results in the damage of property and is often a misdemeanor offense.

4.5. Factors to Be Considered

The following factors are relevance to most investigations when there is a possibility that the criminal act of arson was committed:

(1) Was the creation, starting, or maintaining of a fire or the causing of an explosion intentional?

(2) Was another person present in or on the property?

(3) Who owned the property?

(4) If the property involved was a building, what type of building and what type of occupancy was involved in the fire?

(5) Did the perpetrator act recklessly, though aware of the risk present?

(6) Was there actual presence of flame?

(7) Was actual damage to the property or bodily injury to a person caused by the fire or explosion?

4.6. Fire Patterns

A fire pattern is an identifiable shape or progression of fire effect(s). Each fire pattern requires an analysis that leads to a hypothesis about what generated it and a test of that hypothesis. The investigator typically assigns an interpretation to each fire pattern as to how it may have been created, which in turn assists the investigator in determining how the fire spread. This process has significant potential for uncertainty, as the initial conditions are generally unknown to the investigator.

4.6.1. Dynamics of Pattern Production

The recognition, identification, and proper analysis of fire patterns depend on an understanding of the dynamics of fire development and heat and flame spread. This recognition, identification, and proper analysis require an understanding of the way that conduction, convection, and radiation produce the fire effects and the nature of flame, heat, and smoke movement within a structure.

4.6.2. Locations of Patterns

Fire patterns may be found on any surface that has been exposed to the effects of the fire or its by-products. These surfaces include interior surfaces, external surfaces and structural members, and outside exposures surrounding the fire scene. Interior surfaces commonly include walls, floors, ceilings, doors, windows, furnishings, appliances, machinery, equipment, other contents, personal property, confined spaces, attics, closets, and the insides of walls. Exterior surfaces commonly include walls, eaves, roofs, doors, windows, gutters and downspouts, utilities (e.g., meters, service drops), porches, and decks. Outside exposures commonly include outbuildings, adjacent structures, trees and vegetation, utilities (e.g., poles, lines, meters, fuel storage tanks, and transformers), vehicles, and other objects. Patterns can also be used to determine the height at which burning may have begun within the structure.

4.6.3. Walls and Ceilings

Fire patterns are often found on walls and ceilings. As the hot gas zone and the flame zone of the fire plume encounter these obstructions, patterns are produced that investigators may use to trace a fire’s origin.

4.6.4. Walls

Patterns on walls may appear as lines of demarcation on the surfaces of the walls or may be manifested as deeper burning. Once the surface coverings of a wall are destroyed by burning, the underlying construction can also display various patterns. These patterns are most commonly V patterns, U patterns, hourglass patterns, and spalling. Surfaces behind wall coverings, even when the covering is still in place, can sometimes also display patterns.

4.6.5. Ceilings

The investigator should examine patterns that occur on ceilings or the underside of such horizontal surfaces as tabletops or shelves. The buoyant nature of fire gases concentrates the heat energy at horizontal surfaces above the heat source. Therefore, the patterns that are created on the underside of such horizontal surfaces can indicate the locations of heat sources. Although areas immediately over the source of heat and flame will generally experience heating before the other areas to which the fire spreads, circumstances can occur where fuel at the origin burns out quickly, but the resulting fire spreads to an area where a larger supply of fuel can ignite and burn for a longer period of time. This process can cause more damage to the ceiling in that area than in the area immediately over the origin.

4.6.6. Floors

The investigators should examine patterns that occur on floor coverings and floors. The transition through flashover to full room involvement is associated with a radiant heat flux that exceeds approximately 20 kW/m^2 (2 W/cm^2) at floor level, a typical value for the radiant ignition of common combustible materials. Post-flashover or full room involvement conditions can typically produce fluxes in excess of 170 kW/m^2 and may create, modify, or obliterate patterns.

4.6.7. Outside Surfaces

External surfaces of structures can display fire patterns. In addition to the regular patterns, both vertical and horizontal external surfaces can display burn-through. All other variables being equal, these burn-through areas can identify areas of intense or long-duration burning.

4.6.8. Drop Down (Fall Down)

Burning debris can fall and burn upward, creating a new pattern from this heat source. This occurrence is known as *drop down*. Drop down can ignite other combustible materials, producing low burn patterns.

4.6.9. Location of Objects

Certain types of patterns can be used to locate the positions of objects as they were during a fire.

4.6.10. Penetrations of Horizontal Surfaces

Penetrations in a downward direction are often considered unusual because the more natural direction of heat movement is upward because of the buoyancy of heated gases. In fully involved compartments, however, hot gases may be forced through small, pre-existing openings in a floor, resulting in a penetration. Penetrations may also arise as the result of intense burning under furniture items such as polyurethane mattresses, couches, or chairs. Flaming or smoldering under collapsed floors or roofs can also cause floor penetrations.

CHAPTER FIVE

5.0. PATTERN GENERATION

The fire patterns are evaluated and attributed to the fire dynamics variables or construction features (e.g., damage associated with seams in drywall) that generated the damage. Attributing a fundamental interpretation to an observation, specifically one that ties the underlying physics to an observation, is a major key to accurately determining the true fire scenario and area of origin.

5.1. Plume-Generated Patterns

During the course of a fire, many plumes are likely to be generated as new fuel packages become involved. Fire plumes are three-dimensional. Plume patterns represent demarcation lines of fire effects upon materials created by the three-dimensional (conical) shape of the fire plume being cut (truncated) by an intervening two-dimensional surface such as a ceiling or a wall. When the plume intersects with surfaces, it creates effects that are interpreted as patterns (conical sections). The rate of heat release of the burning fuel has a profound effect on the shape of the fire patterns produced. These fire patterns have been described as the following shapes:

a) V patterns
b) Inverted cone patterns
c) Hourglass patterns
d) U-shaped patterns
e) Pointer and arrow patterns
f) Circular-shaped patterns
g) Truncated Cone Patterns.

5.1.1. V Patterns on Vertical Surfaces:

5.1.1.1. Observations

The V pattern often appears as lines of demarcation (*see fig. 1*) defining the borders of the fire effects as shown in figure 2 through

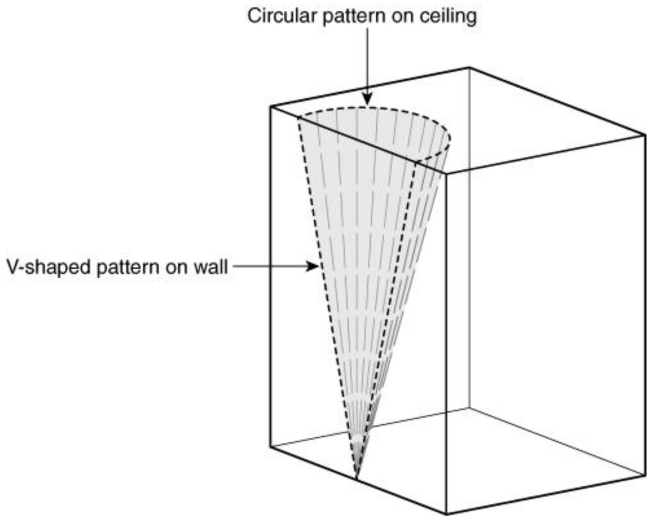


Figure 1 Idealized Formation of V Pattern and Circular Pattern.

Figure 2 V Pattern on Wall Above Stove.

5.1.1.2. Fire Dynamics of V Pattern Development.

Fire plumes can create angled lines of demarcation on nearby vertical surfaces, often times in the shape of a V. The V-shaped pattern is created by thermal damage from the flame or fire plume often created by a burning object next to the vertical surfaces, convective or radiated heat from hot fire gases, or smoke within the fire plume.

The angle of the V-shaped pattern is dependent on several variables, including the following:

a) Heat release rate (HRR)
b) Geometry of the fuel
c) Effects of ventilation

d) Combustibility of the surface on which the pattern appears
e) Presence of horizontal surfaces such as ceilings, shelves, table tops, or the overhanging construction on the exterior of a building

5.1.1.3. Limitations.

The investigator is cautioned that a V shape is not necessarily associated with the origin of the fire as they can also be created due to protected areas from contents, combustion due to ventilation flow paths, and dropdown. The angle of the borders of the V pattern does not indicate the speed of fire growth or rate of heat release of the fuel alone that is, a wide V does not indicate a slowly growing ("slow") fire, and a narrow V does not indicate a rapidly growing ("fast") fire. The angle of the borders of the V pattern does not indicate the speed of fire growth or rate of heat release of the fuel alone; that is, a wide V does not indicate a slowly growing ("slow") fire and a narrow V does not indicate a rapidly growing ("fast") fire.

5.1.2. Inverted Cone (Triangular) Patterns.

5.1.2.1. Observations

A short flame plume burning near to a vertical surface that does not have sufficient HRR may create angled lines of demarcation in a pattern in the shape of a triangle. The characteristic two-dimensional shape is triangular with the base at the bottom. *[See figure 3 and 4 below.]*

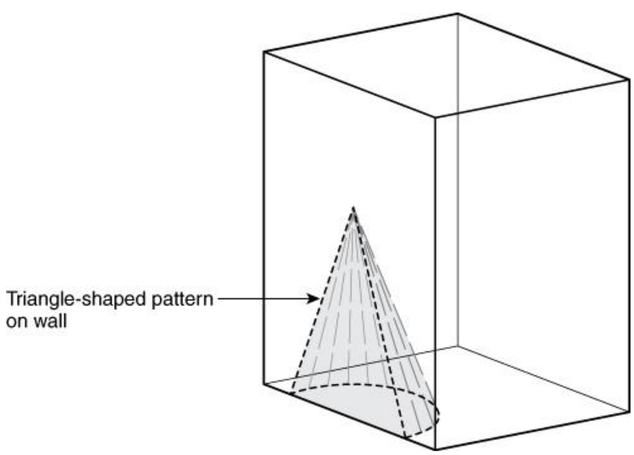


Figure 1 Idealized Formation of an Inverted Cone Pattern.

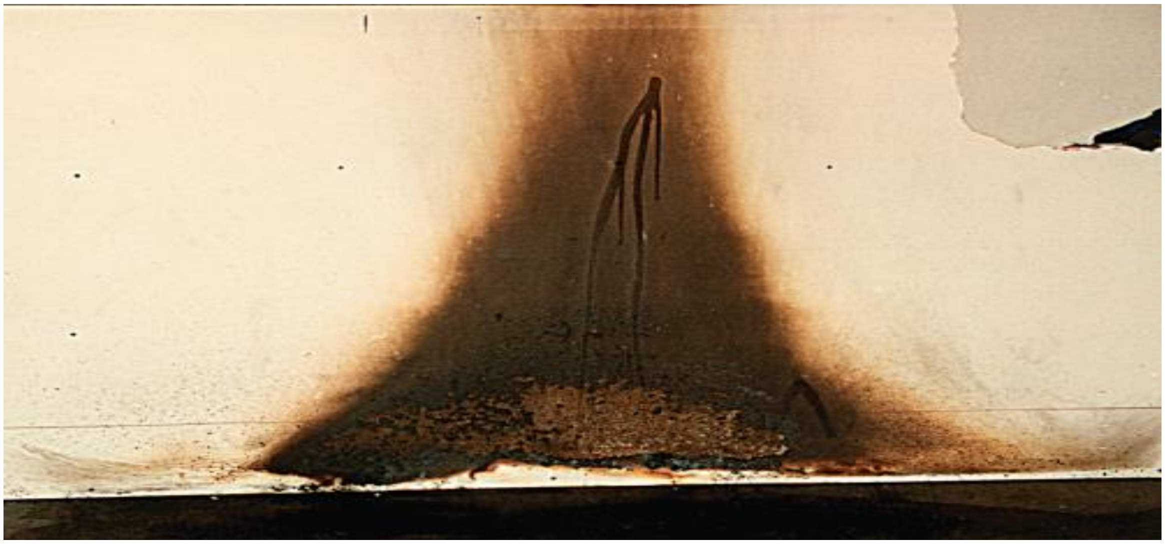


Figure 2 Inverted Cone Pattern Produced by Burning a Small Pile of Newspapers.

5.1.2.2. Fire Dynamics of Inverted Cone Patterns.

Inverted cones are commonly caused by the vertical flame plumes not reaching the ceiling.

5.1.2.2.1. Inverted Cone Patterns with Natural Gas.

The burning of leaking natural gas tends to produce inverted cone patterns, especially if the leakage occurs from below floor level and escapes above at the intersection of the floor and a wall, as in figure 5. The subsequent burning often does not reach the ceiling and is manifested by a characteristic triangular inverted cone pattern shape.

Figure 5 Inverted Cone Pattern Fueled by a Natural Gas Leak Below the Floor Level.

5.1.2.3. Limitations

Inverted cone patterns have been interpreted as proof of ignitible liquid fires, but any fuel source (leaking fuel gas, Class A fuels, etc.) that produces flame zones that do not become vertically restricted by a horizontal surface, such as a ceiling or furniture, can produce inverted cone patterns.

5.1.3. Hourglass Patterns

The plume is a hot gas zone shaped like a V with a flame zone at its base. The flame zone is shaped like an inverted V. When the hot gas zone intersects a vertical surface, the typical V pattern is formed. If the fire itself is very close to or in contact with the vertical surface, the resulting pattern will show the effects of both the hot gas zone and the flame zone together as a large V above an inverted V. The inverted V is generally smaller and may exhibit more intense burning or clean burn. The overall pattern that result is called an hourglass. *(See figure 6)*

Figure 6 Hourglass Pattern.

5.1.4. U-Shaped Patterns

U patterns are similar to the more sharply angled V patterns but display gently curved lines of demarcation and curved rather than angled lower vertices. *(See 7 and 8)* The lowest lines of demarcation of the U patterns are generally higher than the lowest lines of demarcation of corresponding V patterns that are closer to the heat source.

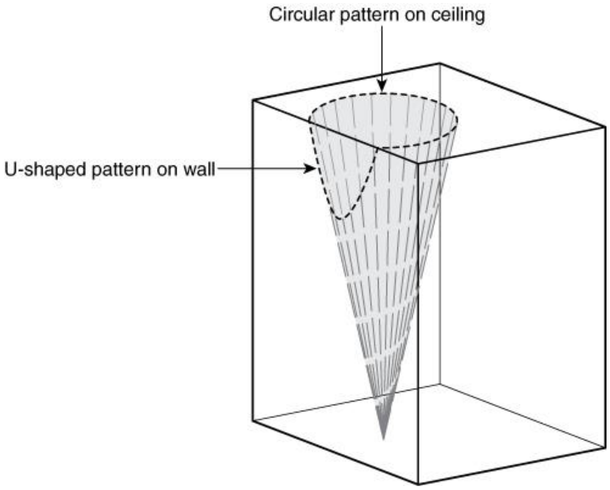


Figure 7 Idealized Formation of U-Shaped Pattern.

Figure 8 U-Shaped Pattern on Wallboard and Studs.

5.1.5. Circular-Shaped Patterns

Patterns on the underside of horizontal surfaces, such as ceilings, tabletops, and shelves, can appear in roughly circular shapes. The farther the heat source is from the wall, the more circular the patterns may appear. Portions of circular patterns can appear on the underside of surfaces that partially block the heated gases or fire plumes. This appearance can occur when the edge of the surface receiving the pattern does not extend far enough to show the entire circular pattern or when the edge of the surface is adjacent to a wall. Within the circular pattern, the center may show more heat degradation, such as deeper charring. By locating the center of the circular pattern, the investigator may find a valuable clue to the source of greatest heating, immediately below.

5.1.6. Truncated Cone Patterns

Truncated cone patterns, also called truncated plumes, are three-dimensional fire patterns displayed on both horizontal and vertical surfaces. It is the intersection or truncating of the natural cone-shaped or hourglass-shaped plume by these vertical and horizontal surfaces that causes the patterns to be displayed. Many fire patterns, such as V patterns, U patterns, circular patterns, are related directly to the three-dimensional cone of heat created by the fire.

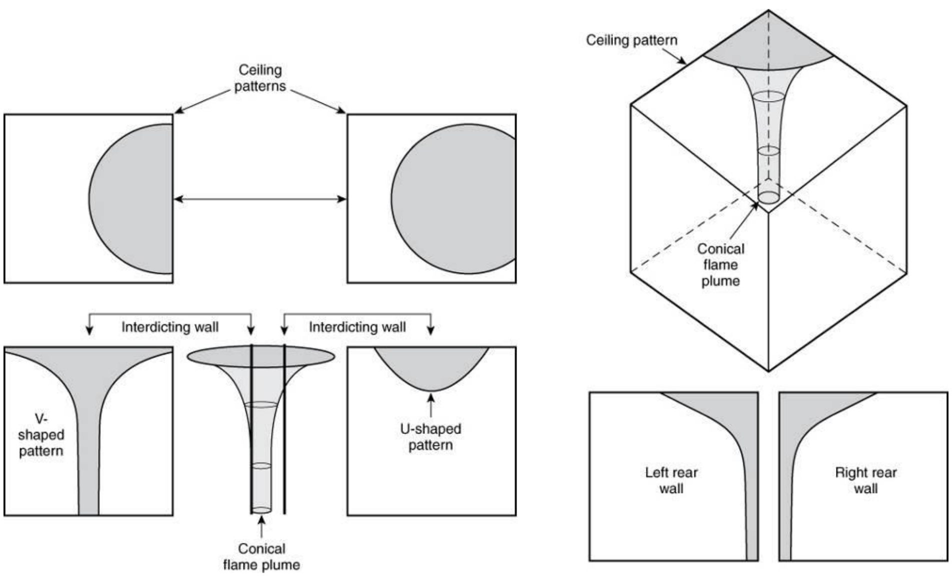


Figure 9 Idealized Truncated Cone Pattern Formation.

Figure 10 Truncated Cone Pattern Displayed on Perpendicular Walls.

5.1.7. Irregular Patterns

Irregular patterns are common in situations of post-flashover conditions, long extinguishing times, or building collapse. These patterns may result from the effects of hot gases, flaming and smoldering debris, melted plastics, or ignitible liquids. Pooled ignitible liquids that soak into flooring or floor covering materials as well as melted plastic can produce irregular patterns. These patterns can also be produced by localized heating or fallen fire debris.

5.1.7.1. Limitations

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

5.1.8. Doughnut-Shaped Patterns

A doughnut-shaped pattern, where an irregularly shaped burn area surrounds a less burned area, may result from an ignitible liquid. When a liquid causes this pattern, shown figure 12 below, it is due to the effects of the liquid cooling the center of the pool as it burns, while flames at the perimeter of the doughnut produce charring of the floor or floor covering. When this condition is found, further examination should be conducted for supporting evidence of ignitible liquids, especially on the interior of the pattern.

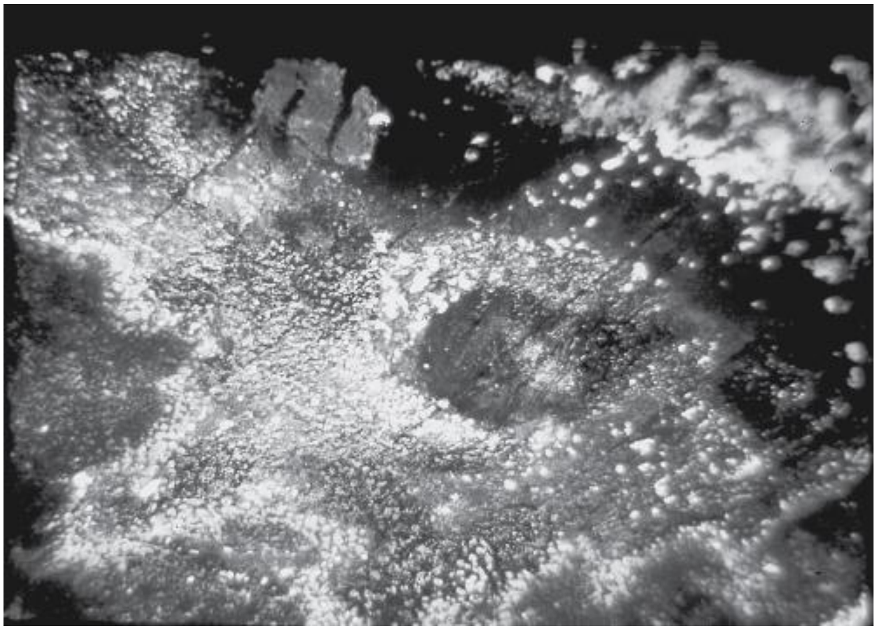


Figure 12 Photograph Showing Doughnut-Shaped Fire Pattern Formation on Carpet

Flooring. Illustrates how Flooring is Degraded at the Perimeter of the Pattern Due to Elevated Temperature from the Flame, While Interior Flooring Temperatures Remain Relatively Cool, and the Flooring Remains Intact Due to Evaporative Cooling of the Liquid Fuel that Still Remains.

5.1.9. Linear Patterns

Patterns that have overall linear or elongated shapes can be called *linear patterns*. Linear patterns usually appear on horizontal surfaces.

5.1.9.1. Protected Floor Areas

Often when the floor area is cleared of debris to examine damage, long, wide, straight patterns will be found, showing areas of extensive heat damage bounded on each side by undamaged or less damaged areas. These patterns often have been interpreted to be “trailers.” While this is possible, the presence of furniture, stock, counters, or storage may result in these linear patterns.

5.1.9.2. Fuel Gas Jets

Jets of ignited fuel gases, such as LP-Gas or natural gas, can produce linear patterns or lines of demarcation, particularly on noncombustible surfaces.

Figure 13 Trailer Running from Doorway Toward the Bottom of the Photograph

Resulting from Burning Gasoline on Carpet.

5.1.9.3. Limitations

Linear patterns may also result from wear on floors and the floor covering due to high traffic. Irregularly shaped objects on the floor, such as clothing or bedding, may also provide protection and produce patterns that may be inaccurately interpreted.

5.2. INVESTIGATION PHOTOGRAPHY AND DOCUMENTATION

5.2.1. Investigation Photography

In order that all Investigation photography is conducted in the same manner the following procedures shall be used anytime photographs are required of a fire scene.

1. Complete a Film Identification Form.
2. Complete a Photography Log Form.
3. Draw rough sketch of scene. (Show approx. distance from the area/subject that is being photographed and direction you are facing.
4. A Film ID Form and Photography Log Form are required for each film roll used on the scene.

5.2.2. Documentation

Efforts to photograph, document, or preserve evidence should apply not only to evidence relevant to an investigator's opinions, but also to evidence of reasonable alternate hypotheses that were considered and ruled out.

5.3. Forms of Discovery

Discovery is the process occurring during the pretrial phase of a legal proceeding where each party to the litigation obtains information, documents, and evidence from opposing parties or nonparties to be used in preparing for trial. Discovery, which is governed by court rules applicable to the jurisdiction in which the case is pending, can take several forms.

CHAPTER SIX

6.0. LEGAL CONSIDERATIONS DURING THE INVESTIGATION.

6.1. Authority to Conduct the Investigation

The investigator should ascertain the basis and extent of his or her authority to conduct the investigation. The authority to investigate is given to Fire and Rescue Force through section 5(2)(c) of the Fire and Rescue Force Act as amended in 2021.

6.2. Request:

a. Upon arrival of the investigator and it is apparent that outside assistance will be required and then the incident commander/investigator will be given such assistance.

b. Should a request from an agency outside the normal coverage area of the Fire and Rescue Force be received, (i.e., City) notify the RFO. The RFO will then authorize the correct response if any.

c. The list of agencies to assist the Fire and Rescue Force with fire investigations can be called in some cases to determine cause and origin, track records of previous fires by occupants, and assist in prosecution of fire related crimes.

d. It shall be noted that the only person who can request assistance from outside agencies shall be the RFO.

CHAPTER SEVEN

7.0. INVESTIGATIONS OF STRUCTURE FIRES

The following procedures along with those mentions in the Building Regulations that have been developed to serve as a SOP during the investigation of structure fires by the fire investigator.

a. Begin the Structure Fire Investigation Report.
b. Begin the Fire Investigation of the structure:
   1. Walk around the perimeter looking for any unusual circumstances such as burn patterns, containers etc. If possible, look under the structure for unusual conditions such as piles of rags, paper, or wood.
   2. After a complete perimeter check begin inside the structure at the least burned area. While conducting the interior check look for missing personal items (pictures, clothes, appliances, personal hygiene items, food etc.)
   3. Inspect the electrical system. Does the breaker panel show signs of shorts? Are any wires shorted? Is there any solid beading on the ends? Are wires stretched to a fine point?
   4. Were there any extension cords in use? Were they acceptable?
   5. Are the burn patterns on the floors and walls normal?
   6. Is there more than one point of origin?
c. As an investigator, you must first rule out all possible accidental causes before you can assume the fire was intentional.
d. If you find that the fire was intentional, the investigator shall perform the following.
   1. Draw a field sketch of the building containing the following information.
      i. Shape and dimensions of the structure.
      ii. Distance from structure to roadway.
      iii. Layout of the interior with doors/windows.
      iv. Annotate area(s) of origin.
      v. Add standard notes on the sketch.
   2. Photograph the scene.
   3. Collect Evidence.

e. When the investigator has completed the scene fieldwork, an investigation file shall be started. This file will contain the following documentation.

1. Copy of Incident Report
2. Structure Fire Investigation Report
3. Consent to Search
4. All Voluntary Written Statements
5. Individual's Rights Form(s) (if needed)
6. Copy of Casualty Report (if needed)
7. Field Sketches
8. Photography Log Form(s) (if pictures taken)
9. Photo I.D. Form
10. Evidence Log/Chain of Custody Form(s)
11. Investigators Notes.
12. Photographs taken of scene (if developed)
13. Any additional information and forms required.

7.1. VEHICLE FIRE INVESTIGATIONS

The following procedures have been developed to serve as a guideline during the investigation of vehicle fires by the fire investigator.

a. Begin the Vehicle Fire Investigation Report.

b. Begin the Vehicle Investigation:

1. Walk around the vehicle for a complete overview.
2. Check area for containers that may have been used for flammable liquids.
3. Look for unusual burn patterns, and/or trailers from the scene.
4. Look under the vehicle: Is the transmission, Driveshaft and gas tank in place?
5. Check the interior of the vehicle to determine if any items are missing? (Stereo, speakers, keys, seats)
6. Were the window's up/down?
7. Is there any unusual odor? (gas, kerosene)
8. Is the Damage to the interior more severe than anywhere else?
9. Check the electrical system for signs of damage. (beading, splicing, signs of arcing)
10. Check the trunk area. (Is spare tire in place? Are there any containers, or

unusual items?)

11. Look in the Engine Compartment. (Is the Battery in place? Carburetor {unless fuel injection}, Are fuel lines intact?)
12. Are all hoses and wiring intact or remnants?
13. Was the Gas cap in place?
14. Take necessary photographs.
15. Take necessary samples.
16. Obtain business card from wrecker service that responds.
17. Begin follow-up procedure.

c. If it is necessary for the vehicle to be impounded, for reasons such as incomplete investigation, suspicion, or any other reason, the Incident Commander/investigator shall contact dispatch and advise them to contact the vendor under contract. Investigator shall also complete the Vehicle Impoundment Form.

d. The investigator shall remain on the scene until the wrecker service arrives, they shall inform the driver of the wrecker that the vehicle is to be impounded and only Fire and Rescue force authorized personnel shall be allowed to examine the vehicle.

e. If the vehicle fire is determined to be accidental and is on a maintained road, the dispatcher will be asked to have the next available wrecker service on the rotation list respond to tow the vehicle. If police are on scene, it is preferred that they make the towing notification.

f. When the investigator has completed the scene fieldwork, an investigation file shall be started. This file will contain the following documentation.

i. Copy of Incident Report.
Ii. Vehicle Fire Investigation Report
iii. Consent to Search
iv. All Voluntary Written Statements
v. Individual’s Rights Form(s) (if needed)
vi. Copy of Casualty Report (if needed)
vii. Field Sketches
viii. Photography Log Form(s) (if pictures taken)
ix. Photo I.D. Form

x. Evidence Log/Chain of Custody Form(s) (if needed)

xi. Investigators Notes.

Xii. Photographs taken of scene (if developed)

Xiii. Vehicle Impoundment Form (if impounded

Xiv. Any additional information and forms required.

7.2. INVESTIGATIONS OF WILDFIRE

Wildfire investigation involves specialized techniques, practices, equipment, and terminology. While the basic principles of fire science and dynamics are the same in a wildfire, the fire development and spread is influenced by different factors such as

1. Wildland fuels,
2. Fire weather,
3. Topography,
4. Unconfined burning.

7.2.1. WILDFIRE FUELS.

Keen observation of variations in wildfire fuels is essential to accurately analyze fire behavior.

7.2.1.1. Fuel Condition Analysis

In a wildland, great differences exist in the character of flammable materials. Deep duff, newly fallen dead leaves, clumps of grass, litters of dry twigs and branches, downed logs, low shrubs, green tree branches, hanging moss, snags, and many other types of material may be present.

Before fuel condition can be analyzed, the physical characteristics of combustible wildland materials must be classified. Such a classification permits the identification of the fuel factors that influence flammability.

7.2.1.2. Ground Fuels

Ground fuels include all flammable materials located between the mineral soil layer and the ground surface. These fuels typically include twig, leaf and needle litter, and decomposing vegetation such as duff, peat moss, buried limbs and roots. Buried limbs and roots can burn along their entire length and ignite a surface fire in a different location. When sufficiently dry, ground fuels can be a very receptive fuel bed for a wide variety of ignition sources due to their high surface area-to-volume ratio.

7.2.1.3. Duff

Duff seldom has a major influence on the spread rate of fire because it is typically moist and tightly compressed so that little of its surface is freely exposed to air, and its rate of combustion is slow. In forest fires, most of the duff can be consumed down to mineral soil. Occasionally, duff contributes to the rate of spread by furnishing a path for the fire to creep along between patches of more flammable material.

7.2.1.4. Roots

Roots are not an important factor in rate of fire spread, as the greatly restricted air supply prevents rapid combustion. However, fires can burn slowly in roots. Some fires have escaped control because a root provided an avenue for the fire to cross the control line. Large roots from dead and partially decayed vegetation will more readily spread fire than the roots of live vegetation.

7.2.1.5. Surface Fuels

Surface fuels are those flammable materials located from the surface of the ground to approximately 2 m (6 ft) above the surface. Surface fuels include grasses, leaves, twigs, needles, field crops, slash and downed limbs. Surface fuels in the one-hour time lag fuel moisture category are the most common materials first ignited. Surface fuels contribute to rapid fire propagation and the rate of fire spread. They also serve as the primary fuel ladder to aerial fuels.

7.2.1.6. Fine Dead Wood

Fine dead wood consists of twigs, small limbs, bark particles, and rotting material. Normally, the fine dead wood classification is confined to material with a diameter of less than 25.4 mm (1 in.). Fine dead wood ignites easily and often provides the main avenue for carrying fire from one area to another. It is the kindling material for larger, heavier fuels.

In areas where a great volume of fine dead wood exists, a fire can develop rapidly. The greatest volume of fine dead wood is usually found in areas containing logging slash. Under dry conditions, the strong convection currents created by the intense heat transport burning embers and carry them out ahead, causing spot fires beyond the main fire front.

7.2.1.7. Grass

Grass, weeds, and other small annual or perennial plants are important surface fuels that influence rate of fire spread. The key factor in these fuels is the degree of curing. Succulent green grass acts as a fire barrier. During the course of a normal fire season, however, grass gradually becomes drier and more flammable as the plant cures or as the stems and leaves die due to lack of moisture. At this time, the grass cover becomes easily ignitable.

Fire investigators need to determine the volume and continuity of the grass cover. In dense forests where little sunlight reaches the ground, very little grass is found. In more open forests, such as in mature stands of pine, there may be a large amount of grass fuel. If there is a more-or-less continuous cover of dry grass on the forest floor, the spread rate of a fire will be governed largely by that cover, rather than by the heavier fuels normally associated with a forest. Fires in dry grass often have high rates of spread.

7.2.1.8. Downed Logs, Stumps, and Large Limbs

Heavy fuels, such as downed logs, stumps, and large limbs comprise the 100 and 1000-hour time-lag fuel category and therefore require long periods of hot, dry weather before they become highly flammable. When such material reaches a dry state, however, high intensity fires may develop. The most dangerous heavy fuels are those containing stringers of dry wood, or many large checks and cracks. Smooth-surfaced material is less flammable, as it dries out more slowly, has little surface exposed to air, and contains less attached kindling fuel.

7.2.1.9. Aerial Fuels

Aerial fuels are those flammable materials located from approximately 2 m (6ft) above the surface to the crowns of the canopy. These fuels include tree branches, leaves, needles, snags, moss, and tall brush. These fuels are only infrequently the materials first ignited and typically require significant amounts of heat from surface fuels. Combining steep slopes and/or higher wind speeds can easily transition the fire to a running crown fire. Aerial fuels can contribute to rapid fire spread, primarily through the generation of aerial firebrands.

7.3. FUEL SIZE

A major factor governing both the ignitibility and burning rate of a fuel is its diameter. The smaller the fuel element (having a larger surface area-to-mass ratio), the easier it will be to ignite and the faster it will be consumed. These smaller fuels are classified as fine fuels and are comprised of such items as seedlings and small trees, twigs, dry grass, brush, dry field crops, and pine needles and cones. Larger-diameter fuels, classified as heavy fuels, are much more difficult to ignite, and burn at slower rates than that of light fuels. Most often, it requires burning light fuels to serve as kindling to ignite the heavier fuels. Some examples of heavy fuel classifications are large-diameter trees and brush, large limbs, logs, and stumps.

7.4. Fuel Moisture Content

The amount of moisture present in the fuel plays a major role in determining the ignitibility and the rate of fire spread. As the vegetation (fuel) dries out, it becomes more readily ignitable and will burn with greater intensity. Green vegetation, or vegetation having high moisture content is more difficult to ignite and will burn more slowly due to the moisture within the vegetation requiring more heat to evaporate that moisture

7.5. Oil Content

The presence of oil within vegetation typically increases the fuel's ease of ignition, fire intensity, and spread factors.

7.6. Weather

Weather plays a substantial role in the behavior of wildfires. Weather elements can be described as the state of the atmosphere with respect to atmospheric stability, temperature, relative humidity, wind velocity, cloud cover, and precipitation.

7.7. Temperature

The temperature of the ambient air directly influences the temperature of the fuel. The sun is one factor that affects temperature. As the radiant solar energy of the sun heats the ground and vegetation, the fuel becomes more susceptible to ignition. Temperature differences of more than 10°C (18°F) can occur between shaded areas and areas exposed to direct sunlight. Another factor influencing temperature is altitude. The lower air pressure at high altitudes allows the air to expand and cool.

7.8. Relative Humidity

Humidity is the measure of water vapor in the air. Humidity is usually expressed as relative humidity, which is the ratio of the amount of moisture in the air to the amount that a known volume of air at that particular temperature can hold, expressed as a percentage. The moisture in the air directly affects the amount of fuel moisture and vice versa. Dry air will draw moisture out of the vegetation, making it more susceptible to fire. Fine fuels are more responsive to relative humidity than are large fuels. If the air has a high relative humidity, the vegetation will take in some of that moisture, making it less susceptible to ignition, or the moisture may slow the rate of spread of a fire in progress. Warm air can hold more water than can cool air. This is illustrated by early morning dew. As the night air cools, the air loses its ability to hold moisture. The moisture condenses at the air's dew point and forms the dew.

7.9. Wind Influence

Wind greatly affects the speed at which a fire will spread. Wind pushes the flame ahead, resulting in a preheating of the fuel. The wind also assists in drying out vegetation, increasing the ease of ignition. Wind further results in the transport of airborne firebrands that have been carried aloft by the heated convective air column. The accompanying fire wind can blow embers and hot sparks ahead of the main fire to ignite secondary fires in areas of unburned fuel. The different types of wind influencing fire behavior are classified as meteorological, diurnal, foehn, and fire winds.

7.10. Fire Winds

Fire winds are caused by the fire itself. These winds are the result of the rising expanding fire plume. Fire winds influence the spread of the fire.

7.11. TOPOGRAPHY

Topography relates to the form of natural or man-made earth surfaces. Topography affects the intensity and spread of a fire. Winds, as well, are greatly affected by the topography of the land.

7.12. Slope

The slope of an area is determined by measuring the rise over run, or the change in elevation over a given distance. Zones on a given slope are often described as top third, middle third, and bottom third. Slope allows the fuel on the uphill side to be preheated more rapidly than if it were on level ground as the distance between the flame and the fuel is decreased. This allows the fire to burn with more intensity and speed.

7.13. Fire Shape

The parts of a wildland fire are generally described in relation to the type of fire spread occurring at that portion of the perimeter as illustrated in

7.14. Fire Head

The portion of a fire that is moving most rapidly is called the fire head. The direction the local wind is blowing while the fire is burning primarily determines the route of the head's advance, subject to influences of slope and other topographic features. Large fires burning in more than one drainage or fuel type can develop additional heads. The head is generally the area of most rapid fire spread and greatest fire intensity. Fire spread at the head of the fire is referred to as advancing fire.

7.15. Fire Flanks

The fire flanks are located on either side of the head. These are the parts of a fire's perimeter that are roughly parallel to the main direction of fire spread. Fire progression on the flanks of the fire is characterized by less intense fire behavior than at the head of the fire. Fire spread on the flanks of the fire is referred to as lateral fire.

7.16. Fire Heel

The fire heel is located at the opposite end of the fire from the head. The fire at the heel is less intense and is easier to control. Generally, the fire at the heel will be backing or burning slowly against the wind or downslope. Fire spread at the heel of the fire is referred to as backing fire.

7.17. FACTORS AFFECTING FIRE SPREAD

There are numerous factors to be considered when assessing the shape of a wildland fire in order to help locate the general origin area. The major factors are the wind speed, wind direction and the slope. These factors relate directly to the resulting speed and direction of fire spread and create the largest fire effects resulting in the easiest indicators to read.

7.17.1. Lateral Confinement

When wildfires are confined by landforms such as gullies, ravines, or narrow valleys, convective heating by confined gases and radiation feedback from flames and burning vegetation increases the heat release rate of the burning fuels. Rapid fire spread is also enhanced by the acceleration and channeling of wind through these topographical features. These factors may result in a more rapid combustion and spread than that of an unconfined vegetation fire.

7.17.2. Fuel Influence

Following wind and slope, fuel type and characteristics provide the third greatest influence on the rate of spread and fire intensity.

7.17.3. Suppression

Fire suppression is the combination of all activities that lead to the extinguishment of the fire. Suppression includes everything from the initial stage of fire discovery to the final stage of completely extinguishing the fire. Protection by fire crews of potential areas of origin is of extreme importance in establishing the fire origin and cause. It may be useful for the investigator to review and analyze the fire suppression tactics and their effects on spread to assist in identifying the fire origin.

7.17.4. Fire Breaks

Fire breaks, fire lines, or control lines are any natural or man-made barriers used to slow, stop, or reroute the direction of the fire spread by separating the fuel from the fire. Natural fire break examples are bodies of water, cliffs, and areas lacking vegetation or areas where the fuel moisture is higher than that of surrounding area. Examples of man-made breaks include roads, fire lines, pre-burned areas, and barriers of water, retardant, or foam.

7.17.5. Air Drops

An air drop is the aerial application of water or retardant mixture directly onto the fire, onto the threatened area, or along a strategic position ahead of the fire to stop or slow the spread of fire. Air drops may alter fire indicators in or near drop zones.

7.17.6. Firing Out

Firing out is the process of burning the fuel between a fire break and the approaching fire to extend the width of the fire barrier. These fires are normally started at a fire control line (normally on the downwind side of the fire) and are burned back toward the leading edge of the fire. Several different sources of ignition are used, including drip torches, fuses, matches, and helitorches.

7.17.7. Other Natural Mechanisms of Fire Spread

The direction and rate of fire spread may be altered by natural or self-induced means.

7.18. Embers and Firebrands

Embers and firebrands can be lifted by the convective column and fall out or be blown by wind into unburned fuel great distances from the original fire. These embers often start new fires outside the perimeter of the main fire. These new fire origins are referred to as spot fires. Care should be taken to distinguish spot fires from possible independent fires unassociated with the main fire.

7.19. Fire Storms

A fire storm is an intense and violent fire created by strong convective winds produced by a large plume associated with atmospheric instability. The indrafts created by the fire's convection column may be strong enough to uproot vegetation and propel small rocks. One characteristic of a fire storm is the tornadic fire whirls, which accompany the powerful indrafts.

7.20. Animals

Animals and birds can spread fire from flaming fur or feathers. Animals have been set afire accidentally and deliberately to start a wildfire. Burned animals that are fire victims can start fires in unburned areas during their flight. A bird's feathers or an animal's fur can be ignited by contact with power lines and can start a wildfire when the electrocuted body falls to the ground.

CHAPTER EIGHT

8.0. PHYSICAL EVIDENCE

During the course of any fire investigation, the fire investigator is likely to be responsible for locating, collecting, identifying, storing, examining, and arranging for testing of physical evidence. The fire investigator should be thoroughly familiar with the recommended and accepted methods of processing such physical evidence.

Physical evidence, defined generally, is any physical or tangible item that tends to prove or disprove a particular fact or issue. Physical evidence at the fire scene may be relevant to the issues of the origin, cause, spread, or the responsibility for the fire.

The decision on what physical evidence to collect at the incident scene for submission to a laboratory or other testing facility for examination and testing, or for support of a fact or opinion, rests with the fire investigator. This decision may be based on a variety of considerations, such as the scope of the investigation, legal requirements, or prohibition. Additional evidence may also be collected by others, including other investigators, insurance company representatives, manufacturer's representatives, owners, and occupants. The investigator should also be aware of standards and procedures relating to evidentiary issues and those issues related to spoliation of evidence.

8.1. Preservation of the Fire Scene and Physical Evidence

General

Every attempt should be made to protect and preserve the fire scene, because evidence could be easily be destroyed or lost in an improperly preserved fire scene.

Generally, the cause of a fire or explosion is not known until near the end of the investigation. Therefore, the evidentiary or interpretative value of various pieces of physical evidence observed at the scene may not be known until, at, or near the end of the fire scene examination, or until the end of the complete investigation. As a result, the entire fire scene should be considered physical evidence and should be protected and preserved. Consideration should be given to temporarily placing removed ash and debris into bags, tarps, or other suitable containers labeled as to the location from which it was removed. This way, if components from an appliance or an incendiary device are found to be missing, they can be more easily found in a labeled container.

The responsibility for the preservation of the fire scene and physical evidence does not lie solely with the fire investigator, but should begin with arriving fire-fighting units or police authorities. Lack of preservation may result in the destruction, contamination, loss, or unnecessary movement of physical evidence. Initially, the incident commander and, later, the fire investigator should secure or ensure the security of the fire scene from unnecessary and unauthorized intrusions and should limit fire suppression activities to those that are necessary.

Evidence at the fire scene should be considered not only in a criminal context, such as in traditional forensic evidence (e.g., weapons, bodily fluids, footprints), nor should it be limited to arson-related evidence, items, or artifacts, such as incendiary devices or containers. Potential evidence at the fire scene and surrounding areas can include the physical structure, the contents, the artifacts, and any materials ignited or any material on which fire patterns appear.

8.2. Fire Patterns as Physical Evidence

The evidentiary and interpretative use of fire patterns may be valuable in the identification of a potential ignition source, such as an incendiary device in an arson fire or an appliance in an accidental fire. Fire patterns are the visible or measurable physical effects that remain after a fire. These include thermal effects on materials, such as charring, oxidation, consumption of combustibles, smoke and soot deposits, distortion, melting, color changes, changes in the character of materials, structural collapse, and other effects.

8.3. Artifact Evidence

Artifacts can be the remains of the material first ignited, the ignition source, or other items or components in some way related to the fire ignition, development, or spread. An artifact may also be an item on which fire patterns are present, in which case the preservation of the artifact is not for the item itself but for the fire pattern that is contained thereon.

8.4. Protecting Evidence

There are a number of methods that can be utilized to protect evidence from destruction. Some methods include posting a fire fighter or police officer as a sentry to prevent or limit access to a building, a room, or an area; use of traffic cones or numerical markers to identify evidence or areas that warrant further examination; covering the area or evidence with tarpaulins prior to overhaul; or isolating the room or area with rope, caution tape, or police line tape. The investigator may benefit from supervising overhaul and salvage operations.

Items found at the fire scene, such as empty boxes or buckets, may be placed over an artifact. However, these items may not clearly identify the artifact as evidence that should be preserved by fire fighters or others at the fire scene. If evidence is not clearly identified, it may be susceptible to movement or destruction at the scene.

8.5. Flag, Bag, Tag

During the examination of the scene it can be useful to identify, protect, and mark items of interest or items that could be potential evidence. Such marking can alert investigators to those items of interest and begin the documentation process.

8.5.1. Flag

The utilization of inexpensive plastic flagging to identify items or areas of interest to protect can aid the ongoing investigation. The flagging alerts others on-scene not to disturb or remove those items. Marking the items of interest can be especially important when using heavy equipment or assistants who are not fire investigators. Different colors of flagging can be used to identify items such as electrical wiring or gas lines. The bright colors also help identify those items when taking photographs, especially large-scale photographs used to show the layout of such utilities. The use of the flagging starts with the initial walk-through of the scene and continues through reconstruction of the contents in the area of origin.

8.5.2. Bag

Items of unknown evidentiary value are frequently located during the scene examination. Bagging can assist preservation of those items. The item of interest should be documented in place and then can be placed in a plastic bag (or another appropriate container). This can be especially important if an item contains small or fragile pieces that might be further disturbed during the normal scene examination process. In some cases, the debris in the immediate area of the item could be placed into separate containers for later, closer examination. The item can be left in place in case it is needed as evidence or to assist other investigators who may later examine the scene. If the item is later needed as evidence, it has been preserved in place and can be collected using the normal evidence collection procedures.

8.5.3. Tag

During the course of normal scene examination, it may be necessary to move items from their original position. The investigator can tag those items, noting information of importance such as location, orientation, or alteration. The tagging can assist later reconstruction of the scene contents or investigators who later examine the scene, or if the item is later collected as evidence.

8.6. Role and Responsibilities of Fire Suppression Personnel in Preserving the Fire Scene

Generally, fire officers and fire fighters have been instructed during basic fire training that they have a responsibility at the fire scene regarding fire investigation.

In most cases, this responsibility is identified as recognizing the indicators of incendiarism, such as multiple fires, the presence of incendiary devices or trailers, and the presence of ignitable liquids at the area of origin. While this is an important aspect of their responsibilities in the investigation of the fire cause, it is only a small part.

Prompt control and extinguishment of the fire protects evidence. The ability to preserve the fire scene is often an important element in the investigation. Even when fire officers and fire fighters are not responsible for actually determining the origin or cause of the fire, they play an integral part in the investigation by preserving the fire scene and physical evidence.

8.6.1. Preservation

Once an artifact or other evidence has been discovered, preliminary steps should be taken to preserve and protect the item from loss, destruction, or movement. The person making the discovery should notify the incident commander as soon as practical. The incident commander should notify the fire investigator or other appropriate individual or agency with the authority and responsibility for the documentation and collection of the evidence.

8.6.2. Caution in Fire Suppression Operations

Fire crews should avoid causing unnecessary damage to evidence when using straight-stream hose lines, pulling ceilings, breaking windows, collapsing walls, and performing overhaul and salvage.

8.6.3. Use of Water Lines and Hose Streams

When possible, fire fighters should use caution with straight-stream applications, particularly at the base of the fire, because the base of the fire may be the area of origin. Evidence of the ignition source can sometimes be found at the area of origin. The use of hose lines, particularly straight-stream applications, can move, damage, or destroy physical evidence that may be present.

A. The use of water hose lines for overhaul operations such as washing down, or for opening up walls or ceilings, should also be restricted to areas away from possible areas of origin.

B. The use of water should be controlled in areas where the investigator may wish to look at the floor for possible fire patterns. When draining the floor of standing water, the drain hole should be located so as to have the least impact on the fire scene and fire patterns.

8.6.4. Overhaul.

A. It is during overhaul that any remaining evidence not damaged by the fire is susceptible to being destroyed or displaced. Excessive overhaul of the fire scene prior to the documentation and analysis of fire patterns can affect the investigation, including failure to determine the area of origin.

B. While the fire fighters have a responsibility to control and extinguish the fire and then check for fire extension, they are also responsible for the preservation of evidence. These two responsibilities may appear to be in conflict and, as a result, it is usually the evidence that is affected during the search for hidden fire. However, if overhaul operations are performed in a systematic manner, both responsibilities can be met successfully.

8.6.5. Salvage

The movement or removal of artifacts from a fire scene can make the reconstruction difficult for the investigator. If the investigator cannot determine the pre-fire location of the evidence, the analytical or interpretative value of the evidence may be lost. Moving, and particularly removing, contents and furnishings or other evidences at the fire scene should be avoided until the documentation, reconstruction, and analysis are completed.

8.6.6. Movement of Knobs and Switches

Fire fighters should refrain from turning knobs and operating switches on any equipment, appliances, or utility services at the fire scene. The position of components, such as the knobs and switches, may be a necessary element in the investigation, particularly in developing fire ignition scenarios or hypotheses. These components, which are often constructed of plastics, can become very brittle when subjected to heating. Their movement may alter the original post-fire state and may cause the switch to break or to become impossible to relocate in its original post-fire position.

8.6.7. Use of Power Tools

The use of gasoline- or diesel-powered tools and equipment should be controlled carefully because this type of equipment could be a source of contamination. The refueling of any fuel-powered equipment or tools should be done outside the perimeter of the fire scene. Whenever fuel-powered equipment is used on the fire scene, its use and location should be documented and the investigator advised.

8.6.8. Limiting Access of Fire Fighters and Other Emergency Personnel

Access to the fire scene should be limited to those persons who need to be there. This precaution includes limiting fire fighters and other emergency or rescue personnel to those necessary for the task at hand. When possible, the activity or operation should be postponed until the evidence has been documented, protected, evaluated, and collected.

8.7. Role and Responsibilities of the Fire Investigator

If the fire fighters have not taken the preliminary steps to preserve or protect the fire scene, then the fire investigator should assume the responsibility for doing so. Then, depending on the individual's authority and responsibility, the investigator should document, analyze, and collect the evidence.

8.7.1. Practical Considerations

The precautions in this section should not be interpreted as requiring the unsafe or infinite preservation of the fire scene. It may be necessary to repair or demolish the scene for safety or for other practical reasons. Once the scene has been documented by interested parties and the relevant evidence removed, there is no reason to continue to preserve the scene. The decision as to when sufficient steps have been taken to allow the resumption of normal activities should be made by all interested parties known at that time.

8.7.2. Contamination of Physical Evidence

Contamination of physical evidence can occur from improper methods of collection, storage, or shipment. Like improper preservation of the fire scene, any contamination of physical evidence may reduce the evidentiary value of the physical evidence.

8.7.2.1. Contamination of Evidence Containers

Unless care is taken, physical evidence may become contaminated through the use of contaminated evidence containers. For this reason, the fire investigator should take every reasonable precaution to ensure that new and uncontaminated evidence containers are stored separately from used containers or contaminated areas.

One practice that may help to limit a possible source of cross-contamination of evidence collection containers, including steel paint cans or glass jars, is to seal them immediately after receipt from the supplier. The containers should remain sealed during storage and transportation to the evidence collection site. An evidence collection container should be opened only to receive evidence at the collection point, at which time it should be resealed pending laboratory examination.

8.7.2.2. Contamination During Collection

Most contamination of physical evidence occurs during its collection. This is especially true during the collection of liquid and solid accelerant evidence. The liquid and solid accelerant may be absorbed by the fire investigator's gloves or may be transferred onto the collection tools and instruments.

Avoiding cross-contamination of any subsequent physical evidence, therefore, becomes critical to the fire investigator. To prevent such cross-contamination, the fire investigator can wear disposable plastic gloves or place his or her hands into plastic bags during the collection of the liquid or solid accelerant evidence. New gloves or bags should always be used during the collection of each subsequent item of liquid or solid accelerant evidence.

An alternative method to limit contamination during collection is to utilize the evidence container itself as the collection tool. For example, the lid of a metal can may be used to scoop the physical evidence into the can, thereby eliminating any cross-contamination from the fire investigator's hands, gloves, or tools.

Similarly, any collection tools or overhaul equipment such as brooms, shovels, or squeegees utilized by the fire investigator need to be cleaned thoroughly between the collection of each item of liquid or solid accelerant evidence to prevent similar cross-contamination. The fire investigator should be careful, however, not to use waterless or other types of cleaners that may contain volatile solvents.

8.7.2.3. Contamination by Fire Fighters

Contamination is possible when fire fighters are using or refilling fuel-powered tools and equipment in an area where an investigator later tests for the presence or omission of an ignitable liquid. Fire fighters should take the necessary precautions to ensure that the possibility of contamination is kept to a minimum, and the investigator should be informed when the possibility of contamination exists.

8.8. Methods of Collection

The collection of physical evidence is an integral part of a properly conducted fire investigation.

The method of collection of the physical evidence is determined by many factors, including the following:

a) *Physical State.* Whether the physical evidence is a solid, liquid, or gas
b) *Physical Characteristics.* The size, shape, and weight of the physical evidence
c) *Fragility.* How easily the physical evidence may be broken, damaged, or altered
d) *Volatility.* How easily the physical evidence may evaporate

8.9. Documenting the Collection of Physical Evidence

Physical evidence should be thoroughly documented before it is moved. This documentation can be best accomplished through field notes, written reports, sketches, and diagrams, with accurate measurements and photography. The diagramming and photography should always be accomplished before the physical evidence is moved or disturbed. The investigator should strive to maintain a list of all evidence removed and of who removed it.

The purpose of such documentation is twofold. First, the documentation should assist the fire investigator in establishing the origin of the physical evidence, including not only its location at the time of discovery, but also its condition and relationship to the fire investigation. Second, the documentation should also assist the fire investigator in establishing that the physical evidence has not been contaminated or altered.

8.9.1. Collection of Traditional Forensic Physical Evidence

Traditional forensic physical evidence includes, but is not limited to, finger and palm prints, bodily fluids such as blood and saliva, hair and fibers, footwear impressions, tool marks, soils and sand, woods and sawdust, glass, paint, metals, handwriting, questioned documents, and general types of trace evidence. Although usually associated with other types of investigations, these types of physical evidence may also become part of a fire investigation. The recommended methods of collection of such traditional forensic physical evidence vary greatly. As such, the fire investigator should consult with the forensic laboratory that will examine or test the physical evidence.

8.9.2. Collection of Evidence for Accelerant Testing

An accelerant is any fuel or oxidizer, often an ignitable liquid, used to initiate a fire or increase the rate of growth or speed the spread of fire. Accelerant may be found in any state gas, liquid, or solid. Evidence for accelerant testing should be collected and tested.

8.9.2.1. Liquid Accelerant Characteristics

Liquid accelerants have unique characteristics that are directly related to their collection as physical evidence. These characteristics include the following:

i. Liquid accelerants are readily absorbed by most structural components, interior furnishings, and other fire debris.

ii. Generally, liquid accelerants float when in contact with water; however, alcohol is a noted exception.

iii. Liquid accelerants have remarkable persistence (i.e., survivability) when trapped within porous material.

8.9.2.2. Canine-Handler Teams

Canine-handler teams have a role in fire investigations, including assisting in locating and collecting samples for laboratory analysis.

8.9.3. Collection of Liquid Samples for Ignitable Liquid Testing

When a possible ignitable liquid is found in a liquid state, it can be collected using any one of a variety of methods. However, the fire investigator should be certain that the evidence does not become contaminated by whichever method is employed. If readily accessible, the liquid may be collected with a new syringe, eye dropper, pipette, siphoning device, or the evidence container itself. Sterile cotton balls or gauze pads may also be used to absorb the liquid.

This method of collection results in the liquid becoming absorbed by the cotton balls or gauze pads. The cotton balls or gauze pads and their absorbed contents then become the physical evidence that should be sealed in an airtight container and submitted to the laboratory for examination and testing.

8.9.4. Collection of Liquid Evidence Absorbed by Solid Materials

Often, liquid accelerant evidence may be found only where the liquid accelerant has been absorbed by solid materials, including soils and sands. This method of collection merely involves the collection of these solid materials with their absorbed contents.

The collection of these solid materials may be accomplished by scooping them with the evidence container itself or by cutting, sawing, or scraping. Raw, unsealed, or sawed edges, ends, nail holes, cracks, knot holes, and other similar areas of wood, plaster, sheet rock, mortar, or even concrete are particularly good areas to sample. If deep penetration is suspected, the entire cross-section of material should be removed and preserved for laboratory evaluation.

In some solid material, such as soil or sand, the liquid accelerant may absorb deeply into the material. The investigator should therefore remove samples from a greater depth. In those situations where liquid accelerants are believed to have become trapped in porous material, such as a concrete floor, the fire investigator may use absorbent materials such as lime, diatomaceous earth, or non-self-rising flour.

This method of collection involves spreading the absorbent onto the concrete surface, allowing it to stand for 20 to 30 minutes, and securing it in a clean, airtight container. The absorbent is then extracted in the laboratory. The investigator should be careful to use clean tools and containers for the recovery step, because the absorbent is easily contaminated. A sample of the unused absorbent should be preserved separately for analysis as a comparison sample.

8.9.5. Collection of Solid Samples for Accelerant Testing

Solid accelerant may be common household materials and compounds or dangerous chemicals. Because some incendiary materials remain corrosive or reactive, care should be taken in packaging to ensure that the corrosive residues do not attack the packaging container. In addition, such materials should be handled carefully by personnel for their own safety.

8.9.6. Comparison Samples

When physical evidence is collected for examination and testing, it is often necessary to also collect comparison samples.

The collection of comparison samples is especially important in the collection of materials that are believed to contain liquid or solid accelerant. For example, the comparison sample for physical evidence consisting of a piece of carpeting believed to contain a liquid accelerant would be a piece of the same carpeting that does not contain any of the liquid accelerant. Comparison samples allow the laboratory to evaluate the possible contributions of volatile pyrolysis products to the analysis and also to estimate the flammability properties of the normal fuel present.

When collected for the purpose of identifying the presence of accelerant residue, the comparison sample should be collected from an area that the investigator believes is free of such accelerants, such as under furniture or in areas that have not been involved in the fire. Assuming that the comparison sample tests negative for ignitable liquids, any ignitible liquids that are found in the suspect sample can be shown to be foreign to the area when the suspect sample was taken.

It is recognized that comparison samples may be unavailable due to the condition of the fire scene. It is also recognized that comparison samples are frequently unnecessary for the valid identification of ignitible liquid residue. The determination of whether comparison samples are necessary is made by the laboratory analyst, but because it is usually impossible for an investigator to return to a scene to collect comparison samples, they should be collected at the time of the initial investigation.

If mechanical or electrical equipment is suspected in the fire ignition, exemplar equipment may be identified and collected or purchased as a comparison sample.

8.9.7. Collection of Gaseous Samples

During certain types of fire and explosion investigations, especially those involving fuel gases, it may become necessary for the fire investigator to collect a gaseous sample. The collection of gaseous samples may be accomplished by several methods.

The first method involves the use of commercially available mechanical sampling devices. These devices merely draw a sample of the gaseous atmosphere and contain it in a sample chamber or draw it through a trap of charcoal- or polymer-adsorbing material for later analysis.

Another method is the utilization of evacuated air-sampling cans. These cans are specifically designed for taking gaseous samples.

8.9.8. Collection of Electrical Equipment and System Components

Before attempting to collect electrical equipment or components from circuits of a power distribution system, the fire investigator should verify that all sources of electricity are off or disconnected. All safety procedures described should be followed. Electrical equipment and components may be collected as physical evidence to assist the fire investigator in determining whether the component was related to the cause of the fire.

Electrical components, after being involved in a fire, may become brittle and subject to damage if mishandled. Therefore, methods and procedures used in collection should preserve, as far as practical, the condition in which the physical evidence was found. Before any electrical component is collected as physical evidence, it should be thoroughly documented, including being photographed and diagrammed. Electrical wiring can usually be cut easily and removed.

This type of evidence may consist of a short piece, a severed or melted end, or it might be a much longer piece, including an unburned section where the wiring's insulation is still intact. The fire investigator should collect the longest section of wiring practicable so that any remaining insulation can also be examined. Before wires are cut, a photograph should be taken of the wire(s), and then both ends of the wire should be tagged and cut so that they can be identified as one of the following:

(1) The device or appliance to which it was attached or from which it was severed
(1) The circuit breaker or fuse number or location to which the wire was attached or from which it was severed
(2) The wire's path or the route it took between the device and the circuit protector

Electrical switches, receptacles, thermostats, relays, junction boxes, electrical distribution panels, and similar equipment and components are often collected as physical evidence. It is recommended that these types of electrical evidence be removed intact, in the condition in which they were found.

When practical, it is recommended that any fixtures housing such equipment and components be removed without disturbing the components within them. Electrical distribution panels, for example, should be removed intact. An alternative method, however, would be the removal of individual fuse holders or circuit breakers from the panel. If the removal of individual components becomes necessary, the fire investigator should be careful not to operate or manipulate them while being careful to document their position and their function in the overall electrical distribution system.

If the investigator is unfamiliar with the equipment, he or she should obtain assistance from someone knowledgeable regarding the equipment, prior to disassembly or on-scene testing, to prevent damage to the equipment or components.

8.9.9. Collection of Appliances or Small Electrical Equipment

Whenever an appliance or other type of equipment is believed to be part of the ignition scenario, it is recommended that the fire investigator have it examined or tested. Appliances may be collected as physical evidence to support the fire investigator's determination that the appliance was or was not the cause of the fire. This type of physical evidence may include many diverse items, from the large (e.g., furnaces, water heaters, stoves, washers, dryers) to the small (e.g., toasters, coffee pots, radios, irons, lamps).

Where practical, the entire appliance or item of equipment should be collected intact as physical evidence. This includes any electrical power cords or fuel lines supplying or controlling it.

Where the size or damaged condition of an appliance or item of equipment makes it impractical to be removed in its entirety, it is recommended that it be secured in place for examination and testing. Often, however, only a single component or group of components in an appliance or item of equipment may be collected as physical evidence. The fire investigator should strive to ensure that the removal, transportation, and storage of such evidence maintains the physical evidence in its originally discovered condition.

8.10. Evidence Containers

Once collected, physical evidence should be placed and stored in an appropriate evidence container.

Like the collection of the physical evidence itself, the selection of an appropriate evidence container also depends on the physical state, physical characteristics, fragility, and volatility of the physical evidence. The evidence container should preserve the integrity of the evidence and should prevent any change to or contamination of the evidence. Evidence should not be packed directly in loose packing materials, such as “peanuts” or shredded paper, but first placed in a proper bag or container to avoid the loss of small items. Alternatively, the packing material can be placed in bags and packed around the evidence.

Evidence containers may be common items, such as envelopes, paper bags, plastic bags, glass containers, or metal cans, or they may be containers specifically designed for certain types of physical evidence. The investigator's selection of an appropriate evidence container should be guided by the policies and procedures of the laboratory that will examine or test the physical evidence or the use to which the evidence will be subjected.

8.10.1. Accelerant Liquid and Solid Evidence Containers

It is recommended that containers used for the collection of liquid and solid accelerant evidence be limited to four types. These include metal cans, glass jars, special evidence bags, and common plastic evidence bags. The fire investigator should be concerned with preventing the evaporation of the accelerant and preventing its contamination. It is important, therefore, that the container used be completely sealed to prohibit such evaporation or contamination.

8.10.2. Metal Cans

The recommended container for the collection of liquid and solid accelerant evidence is an unused, clean metal can. In order to allow space for vapors to collect, the can should be not more than two-thirds full.

Figure shows Various Types of Metal Cans.

The advantages of using metal cans include their availability, economic price, durability, and ability to prevent the evaporation of volatile liquids.

The disadvantages, however, include the inability to view the evidence without opening the container, the space requirements for storage, and the tendency of the container to rust when stored for long periods of time. If metal cans are used to store bulk quantities of volatile liquids, such as gasoline, high storage temperatures [above 40°C (100°F)] can produce sufficient vapor pressure to force the lid open and cause loss of sample. For such samples, glass jars may be more appropriate.

8.10.3. Glass Jars

Glass jars can also be used for the collection of liquid and solid accelerant evidence. It is important that the jars not have glued cap liners or rubber seals, especially when bulk liquids are collected. The glue often contains traces of solvent that can contaminate the sample, and rubber seals can soften or even dissolve in the presence of liquid accelerants or their vapors, allowing leakage or loss of the sample. In order to allow space for vapor samples to be taken during examination and testing, the glass jar should be not more than two-thirds full.

The advantages of using glass jars include their availability, their low price, the ability to view the evidence without opening the jar, the ability to prevent the evaporation of volatile liquids, and their lack of deterioration when stored for long periods of time.

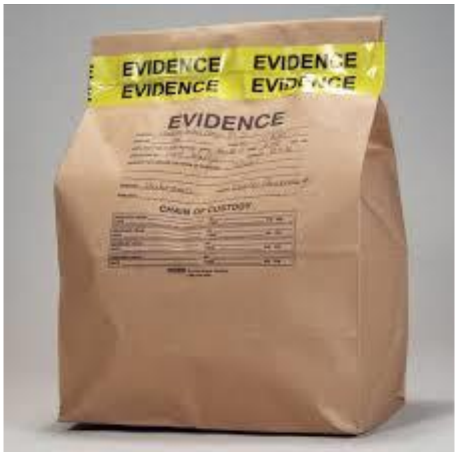
The disadvantages, however, include their tendency to break easily and their physical size, which often prohibits the storage of large quantities of physical evidence.

8.10.4. Special Evidence Bags

Special bags, designed specifically for liquid and solid accelerant evidence, can also be used for collection. Unlike common plastic evidence bags, these special evidence bags do not have a chemical composition that can cause erroneous test results during laboratory examination and during testing of the physical evidence contained in such bags.

The advantages of using special evidence bags include their availability in a variety of shapes and sizes, their economic price, the ability to view the evidence without opening the bag, their ease of storage, and the ability to prevent the evaporation of volatile liquids.

The disadvantages, however, are that they are susceptible to being damaged easily, resulting in the contamination of the physical evidence contained in them, and they may be difficult to seal adequately.



8.10.5. Common Plastic Bags

While they are not generally usable for volatile evidence, common (polyethylene) plastic bags can be used for some evidence packaging. They can be used for packaging incendiary devices or solid accelerant residues, but they could be permeable, allowing for loss and contamination.

The advantages of using common plastic bags include their availability in a variety of shapes and sizes, their economic price, the ability to view the evidence without opening the bag, and their ease of storage.

The disadvantages, however, are their susceptibility to easy damage (tearing and penetration), resulting in the contamination of the physical evidence contained in them, and their marked inability to retain light hydrocarbons and alcohols, resulting in loss of the sample, misidentification, or cross-contamination between containers in the same box.

8.11. Purposes of Canine-Handler Team

Trained and certified canine-handler teams have proven their ability to improve fire investigations in several ways, all of which relate to their main purpose of identifying the possible presence of ignitible liquids. The following are examples of proper uses of such teams:

- (1) Assisting in screening for contamination of fire investigators' tools, evidence containers, and other equipment.
- (2) Assisting in locating the presence of ignitible liquids. An ignitible liquid might be relevant as the first fuel ignited, a content fuel, or an accelerant. The examinations conducted by the team may involve buildings or other structures, open areas, vehicles, or personal effects removed from persons known or thought to be present before or during the fire.
- (3) Assisting in the collection of samples for laboratory analysis for ignitible liquids.
- (4) Assisting with the examination of debris (loose or packaged) removed from the immediate scene as a screening step to confirm whether the appropriate debris has been recovered for laboratory analysis.

8.12. Legal Considerations for Examinations or Searches

Some types of examinations or searches may require consent by the person in lawful control of property or a search warrant.

8.13. Using Canine-Handler Teams to Help Avoid Bias

When used properly as outlined in this section, the use of canine-handler teams can help to avoid expectation and confirmation bias.

8.14. Avoiding Confirmation Bias

Confirmation bias occurs when an investigator tries to prove rather than disprove a hypothesis. If an investigator hypothesizes that ignitible liquids or accelerants played no role in the cause or spread of a fire, an canine-handler team can be deployed in an effort to disprove this hypothesis. If the canine alerts and a laboratory analysis confirms the presence of an ignitible liquid, the hypothesis is disproven and the investigator has new data to help in the formulation of a new hypothesis.

8.15. Avoiding Expectation Bias

Expectation bias occurs when an investigator reaches a premature conclusion without sufficient data, using the premature determination to dictate investigative processes. Where an investigator only calls in canine-handler team in an effort to prove a belief that the fire was incendiary, a person with an opposing interest might argue the investigator's judgment is influenced by expectation bias. Using canine-handler team is a demonstrable step in collecting relevant data concerning the presence or absence of an ignitible liquid. This is particularly so if an alert is confirmed by laboratory analysis and the investigator explores all reasonable hypothesis for the presence of an ignitible liquid instead of jumping to the conclusion that it was used as an accelerant.

8.16. Legal Proceedings

If reliability becomes an issue, this may be a matter for the handler to be prepared to deal with in legal proceedings.

8.17. Coordinating the Investigation with the Handler

The investigators to have basic knowledge about evidence documentation, collection, and preservation. Whenever specialized personnel or experts are called in to assist with the investigation, including canine-handler team, the investigator or person who is coordinating the investigation should ensure that proper steps are taken respecting evidence documentation, collection, and preservation.

8.18. Responsibility

While the investigator must defer to the expertise of the handler concerning the use of the canine, the responsibilities of the handler and investigator should be coordinated and may overlap when it comes to documentation, collection, and preservation of evidence. Since the investigator (or lead investigator if there is more than one) will ultimately be responsible to ensure the presentation of expert evidence in court is coordinated should the matter become the subject of criminal or civil litigation, an investigator should address with the handler their division of responsibilities respecting evidence. The division of responsibility should be documented.

8.19. Evidence Collection

If the handler is certified or otherwise qualified as an investigator pursuant to NFPA 1033 and competent to deal with evidence at the scene, the handler may be the best one to collect and document the evidence from the canine's alerts. If not, the investigator should become involved with collecting and managing the physical evidence. Whomever collects the evidence should follow the instructions for collecting evidence for ignitible liquid or accelerant testing set.

8.20. Handler Safety

The handler is responsible to consult with the lead investigator or other person responsible for worker safety at the scene. Handlers are responsible to follow the relevant safety provisions.

8.21. Identification of Physical Evidence

All evidence should be marked or labeled for identification at the time of collection, as required.

Recommended identification includes the name of the fire investigator collecting the physical evidence, the date and time of collection, an identification name or number, the case number and item designation, a description of the physical evidence, and where the physical evidence was located. This can be accomplished directly on the container or on a preprinted tag or label that is then securely fastened to the container.

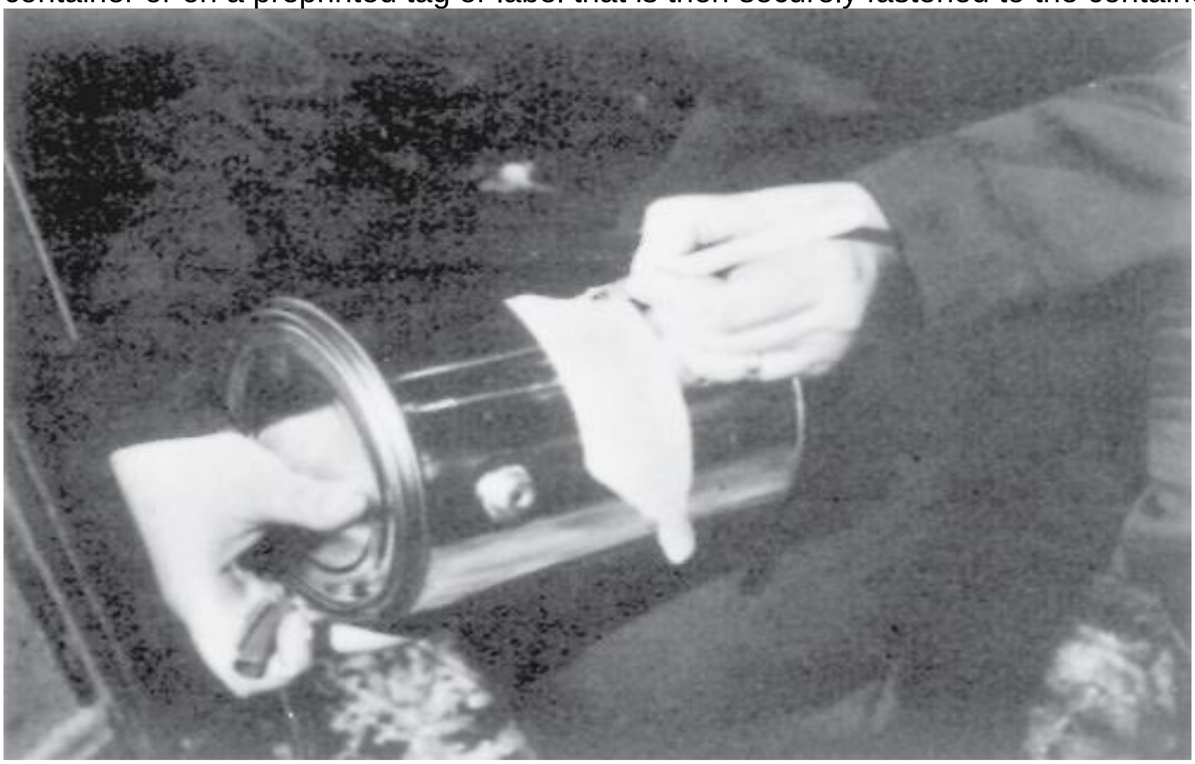


Figure shows Marking of the Evidence Container.

The fire investigator should be careful that the identification of the physical evidence cannot be easily damaged, lost, removed, or altered. The fire investigator also should be careful that the placement of the identification, especially adhesive labels, does not interfere with subsequent examination or testing of the physical evidence at the laboratory.

8.22. Evidence List

The investigator should prepare and maintain complete documentation and a detailed list of all physical evidence collected. This list should identify the evidence by particular case, individual evidence/item number or letter, evidence collection location, and a brief description of the evidence item. The evidence list should be updated as any additional evidence is discovered and collected, or if evidence is divided into subitems during examination or testing.

8.23. Transportation and Storage of Physical Evidence

Transportation of physical evidence to the laboratory or testing facility can be done either by hand delivery or by shipment.

8.23.1. Hand Delivery

Whenever possible, it is recommended that physical evidence be hand delivered for examination and testing. Hand delivery minimizes the potential of the physical evidence becoming damaged, misplaced, or stolen.

During such hand delivery, the fire investigator should take every precaution to preserve the integrity of the physical evidence. It is recommended that the physical evidence remain in the immediate possession and control of the fire investigator until arrival and transfer of custody at the laboratory or testing facility.

The fire investigator should define in writing the scope of the examination or testing desired. This request should include the name, address, and telephone number of the fire investigator; a detailed listing of the physical evidence being submitted for examination and testing; and any other information required, depending on the nature and scope of the examination and testing requested. This request may also include the facts and circumstances of the incident yielding the physical evidence.

8.23.2. Shipment

General

It may sometimes become necessary to ship physical evidence to a laboratory or testing facility for examination and testing. When shipping becomes necessary, the fire investigator should take every precaution to preserve the integrity of that physical evidence.

The fire investigator should choose a container of sufficient size to adequately hold all of the individual evidence containers from a single investigation. Physical evidence from more than one investigation should never be placed in the same shipment.

The individual evidence container should be packaged securely within the shipping container. A letter of transmittal should be included. The letter of transmittal is a written request for laboratory examination and testing. It should include the name, address, and telephone number of the fire investigator; a detailed listing of the physical evidence being submitted for examination and testing; the nature and scope of the examination and testing desired; and any other information required, depending on the nature and scope of the examination and testing requested. This letter of transmittal may also include the facts and circumstances of the incident yielding the physical evidence.

The sealed package should be shipped by registered United States mail or any commercial courier service. The fire investigator should, however, always request return receipts and signature surveillance.

8.23.2.1. Shipping Electrical Evidence

In addition to the procedures, the investigator should be aware that some electrical equipment with sensitive electromechanical components may not be suitable for shipment. Examples include certain circuit breakers, relays, or thermostats. The fire investigator should consult personnel at laboratory or testing facilities for advice on how to transport the evidence.

8.23.2.2. Shipping of Volatile or Hazardous Materials

The fire investigator is cautioned about shipping volatile or hazardous materials. The investigator should ensure that such shipments are made in accordance with applicable federal, state, and local laws. When dealing with volatile evidence, it is important that the evidence be protected from extremes of temperature. Freezing or heating of the volatile materials may affect lab test results. Generally, the lower the temperature at which the evidence is stored, the better the volatile sample will be preserved, but it should not be allowed to freeze.

8.24. Storage of Evidence

Physical evidence should be maintained in the best possible condition until it is no longer needed. It should always be protected from loss, contamination, and degradation. Heat, sunlight, and moisture are the chief sources of degradation of most kinds of evidence. Dry and dark conditions are preferred, and the cooler the better. Opening of sealed evidence bags containing evidence not intended for accelerant testing will allow moisture to evaporate, will better preserve metallic items, and can prevent molding of organic items such as wet clothing. Refrigeration of volatile evidence is strongly recommended. If a sample is being collected for fire-debris analysis, it may be frozen, since freezing will prevent microbial and other biological degradation. However, freezing may interfere with flash point or other physical tests and may burst water-filled containers.

8.25. Chain of Custody of Physical Evidence

The value of physical evidence entirely depends on the fire investigator's efforts to maintain the security and integrity of that physical evidence from the time of its initial discovery and collection to its subsequent examination and testing. At all times after its discovery and collection, physical evidence should be stored in a secured location that is designed and designated for this purpose. Access to this storage location should be limited in order to limit the chain of custody to as few persons as possible. Wherever possible, the desired storage location is one that is under the sole control of the fire investigator.

When it is necessary to pass chain of custody from one person to another, it should be done using a form on which the receiving person signs for the physical evidence. Figure shows an example of such a form.

Crime Scene Search Evidence Report

Name of subject ______________________________

Offense ______________________________

Date of incident __________ Time __________ a.m. p.m.

Search officer ______________________________

Evidence description ______________________________

____

Location ______________________________

____

Chain of Possession

Received from ______________________________

By ______________________________

Date __________ Time __________ a.m. p.m.

Received from ______________________________

By ______________________________

Date __________ Time __________ a.m. p.m.

Received from ______________________________

By ______________________________

Date __________ Time __________ a.m. p.m.

Received from ______________________________

By ______________________________

Date __________ Time __________ a.m. p.m.

Figure shows Chain of Custody Form.

8.26. Examination and Testing of Physical Evidence

Once collected, physical evidence is usually examined and tested in a laboratory or other testing facility. Physical evidence may be examined and tested to identify its chemical composition; to establish its physical properties; to determine its conformity or lack of conformity to certain legal standards; to establish its operation, inoperation, or malfunction; to determine its design sufficiency or deficiency, or other issues that will provide the fire investigator with an opportunity to understand and determine the origin of a fire, the specific cause of a fire, the contributing factors to a fire's spread, or the responsibility for a fire. The investigator should consult with the laboratory or other testing facility to determine what specific services are provided and what limitations are in effect.

8.27. Evidence Collection or Inspections Involving Alteration Without Changes to the Evidentiary Value of the Artifacts

Frequently, the efficient collection and examination of items of physical evidence require that certain alterations be made to the evidence, without which the evidence could not be properly preserved, examined, or evaluated.

These inspections commonly include photography, x-ray, and diagramming; physical measurement of the size, weight, or density of the artifacts (i.e., depth of char and depth of calcination measurements); and testing of such properties as electrical resistance and continuity and ferromagnetism (nature of a metal).

On many occasions the effective collection, inspection, or examination of evidence first requires that unimportant portions of, or debris adhering to an evidence item must be removed or altered in order to gain access to the important evidentiary information, which, by definition, do not change the evidentiary value of the evidence.

Common procedures include the opening or removal of an artifact's cover, outer case, or door; the cutting away or cleaning off of charred or melted material or debris that is obstructing access to an area or information of interest; or the cutting of electrical wires or piping between connections for more efficient examination, collection, or testing *[see Figure through Figure]*. Such procedures, though they may in fact alter portions of the physical evidence, typically do not effectively alter the overall evidentiary value of the item.

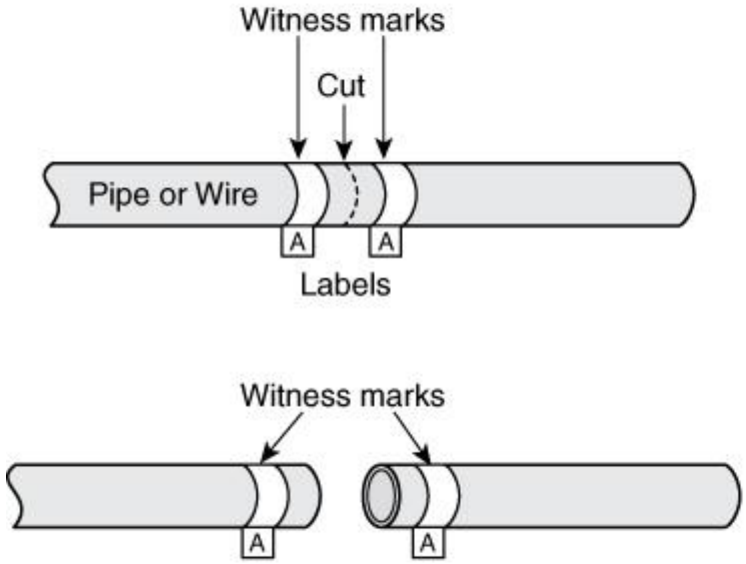


Figure shows (a) A Method of Intrusive, Nondestructive Marking and Cutting of Wires, Electrical Conductors, or Pipes in a Manner that the Relationships of the Severed Ends Will Be Recorded.

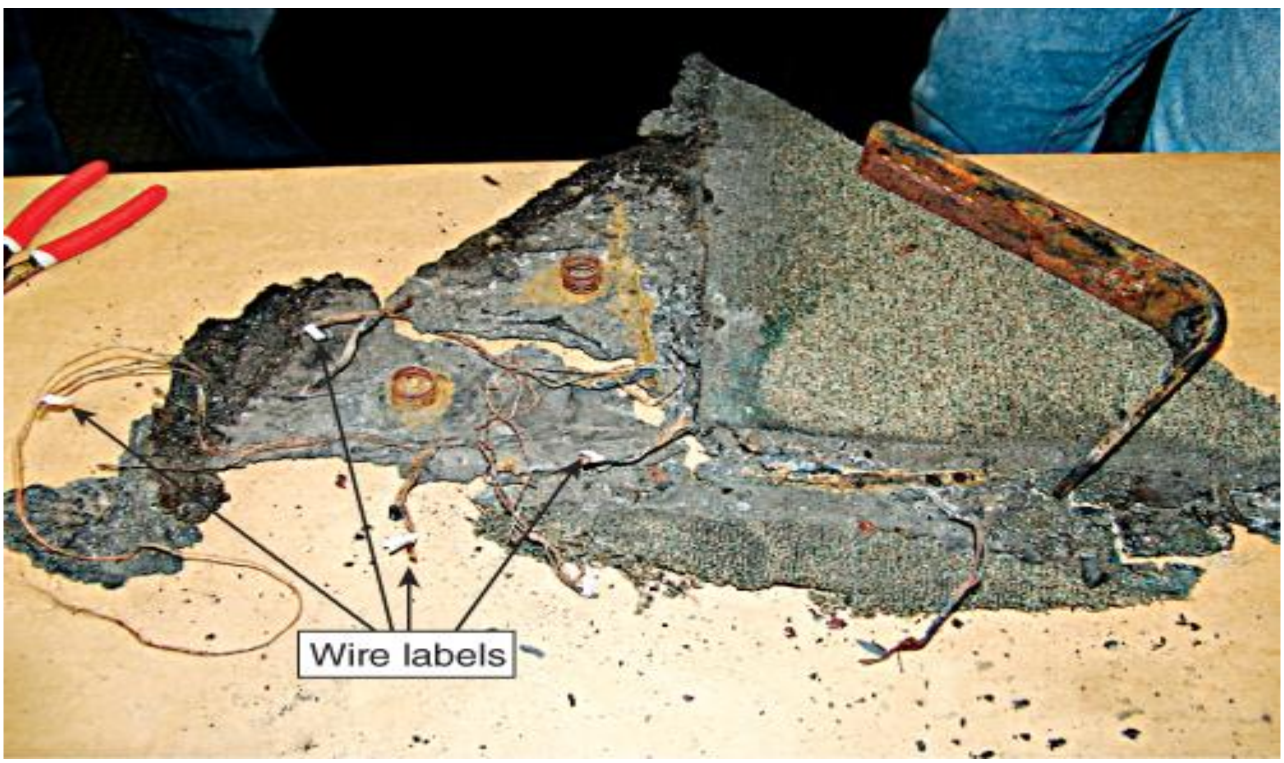


Figure shows (b) Partially Melted Carpet Sample with Cut and Marked Embedded Wires (Note Wire Labels), and Other Evidence Obscured by Melted and Resolidified Carpet Material.

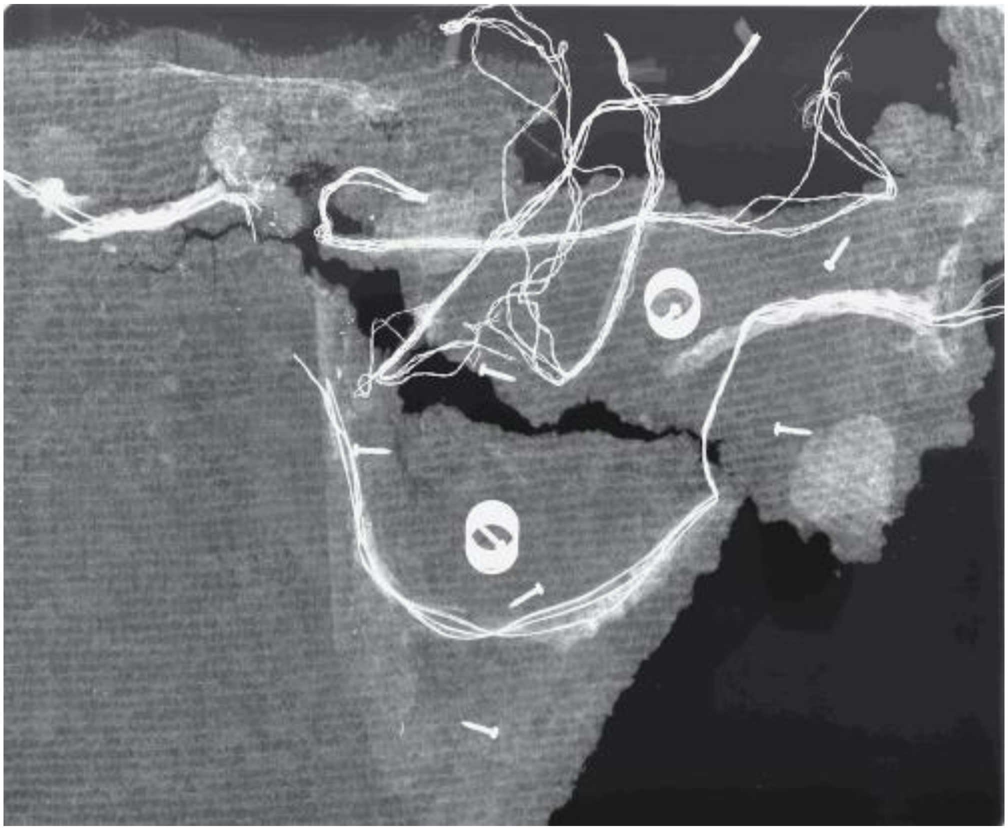


Figure shows (c) X-Ray Image of the Partially Melted Carpet Sample Shown in Figure shows (b), Displaying Hidden Screws and Electrical Conductors.

For example, Figure (b) and Figure (c) display a portion of fire scene floor debris, which could not be x-rayed without removal from the much larger original evidence configuration. Such removal required that four electrical conductors be cut, and their respective end pieces marked.

8.28. Sufficiency of Samples

Fire investigators should be familiar with capabilities and limitations of the scientific laboratory equipment. Not understanding these limitations can result in the fire investigator collecting a quantity of physical evidence that is too small to examine or test.

Certainly, the fire investigator will not always have the opportunity to determine the quantity of physical evidence he or she can collect. Often, the fire investigator can collect only that quantity that is discovered during his or her investigation.

Each laboratory examination or test requires a certain minimum quantity of physical evidence to facilitate proper and accurate results. The fire investigator should be familiar with these minimum requirements. The laboratory that examines or tests the physical evidence should be consulted concerning these minimum quantities.

8.29. Comparative Examination and Testing.

During the course of certain fire investigations, the fire investigator may wish to have appliances, electrical equipment, or other products examined to determine their compliance with recognized standards. Such standards are published by the American Society for Testing and Materials, Underwriters Laboratories Inc., and other agencies.

Another method of comparative examination and testing involves the use of an exemplar appliance or product. Utilizing an exemplar allows the testing of an undamaged example of a particular appliance or product to determine whether it was capable of causing the fire. The sample should be the same make and model as the product involved in the fire.

8.30. Evidence Disposition.

The fire investigator is often faced with disposing of evidence after an investigation has been completed. The investigator should not destroy or discard evidence unless proper authorization is received. Circumstances may require that evidence be retained for many years and ultimately may be returned to the owner.

Criminal cases such as arson require that the evidence be kept until the case is adjudicated. During the trial, evidence submitted — such as reports, photographs, diagrams, and items of physical evidence — will become part of the court record and will be kept by the courts. Volatile or large physical items may be returned to the investigator by the court. There may be other evidence still in the investigator's possession that was not used in the trial. Once all appeals have been exhausted, the investigator may petition the court to either destroy or distribute all of the evidence accordingly. A written record of authorization to dispose of the evidence should be kept. The criminal investigator should be mindful of potential civil cases resulting from this incident, which may require retention of the evidence beyond the criminal proceedings.

CHAPTER NINE

9.0. ORIGIN DETERMINATION

This chapter recommends a methodology to follow in determining the origin of a fire. 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. The purpose of determining the origin of the fire is to identify in three dimensions the locations at which the fire began.

This chapter deals primarily with the determination of origin involving structures; however, the methodology generally applies to all origin determinations. Separate chapters address the particular requirements for determining origin in non-structure fire incidents (motor vehicles, boats, wildfire, etc.).

Determination of the origin of the fire involves the coordination of information derived from one or more of the following:

a) *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

b) *Fire Patterns.* The analysis of effects and patterns left by the fire, which may include patterns involving electrical conductors.

c) *Fire Dynamics.* The analysis of the fire dynamics [i.e., the physics and chemistry of fire initiation, growth and the interaction between the fire and the building's systems]

9.1. Overall Methodology

The overall methodology for determining the origin of the fire is the scientific method as described in Chapter **4**. This methodology includes recognizing and defining the problem to be solved, collecting data, analyzing the data, developing hypotheses, and most importantly, testing the hypothesis or hypotheses. In order to use the scientific method, the investigator must develop at least one hypothesis based on the data available at the time. These hypotheses should be considered “working hypotheses,” which upon testing may be discarded, revised, or expanded in detail as new data is collected during the investigation and new analyses are applied. This process is repeated as new information becomes available.

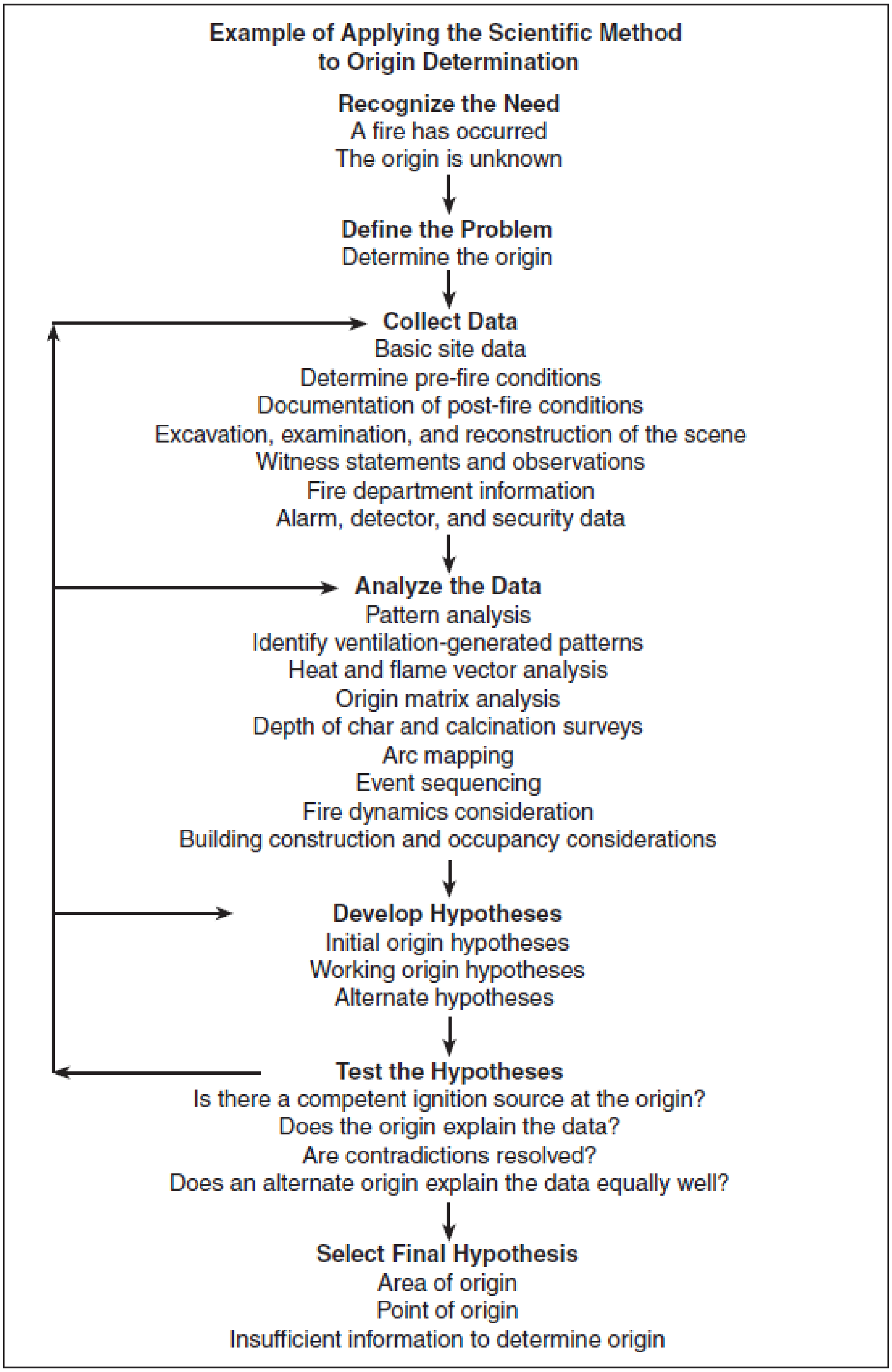


Figure 18.2 An Example of Applying the Scientific Method to Origin Determination.

Testing any origin hypothesis requires an understanding of the associated fire events as well as the growth of the fire and how the fire spread through the structure. A narrow focus on only identifying the first item ignited and a competent ignition source fails to take into account important data that can be used to test any origin hypothesis. In such a narrow focus, the growth and spread of the fire and the resulting fire damage are not well considered.

The purpose of the fire spread analysis is to determine whether the resulting physical damage and available data are consistent with the area of origin hypothesis. For example, a fire starting in a wastebasket is a plausible working hypothesis, but the resulting fire damage would be highly dependent on the position of the first fuel and any subsequently ignited fuels. If the wastebasket had been located in an area with no adjacent fuel, then the results may be significantly different than if the wastebasket had been located next to a polyurethane sofa. Both hypotheses posit the same first item ignited, but the outcome is very different. Thus, if the origin hypothesis is not consistent with the resulting growth and spread of the fire, it is not a valid hypothesis. Fire spread scenarios within a compartment or building should be analyzed using the principles of fire dynamics presented in Chapter **5** and fire pattern development in Chapter **6**.

In some instances, a single item, such as an irrefutable article of physical evidence or a credible eyewitness to the ignition, or a video recording, may be the basis for a determination of origin. In most cases, however, no single item is sufficient in itself. The investigator should use all available resources to develop origin and spread hypotheses and to determine which hypotheses fit all of the evidence available. When an apparently plausible hypothesis fails to fit some item of evidence, the investigator should try to reconcile the two and determine whether the hypothesis or the evidence is erroneous.

In some cases, it will be impossible to fix the point of origin of a fire. Where a single point cannot be identified, it can still be valuable for many purposes to identify the area(s) of origin. In such instances, the investigator should be able to provide plausible explanations for the area of origin with the supporting evidence for each option. Not identifying a point of origin will not necessarily preclude determining an origin and cause. In some situations, the extent of the damage may reduce the ability to specifically identify the point of origin, without removing the ability to put forward credible origin and cause hypotheses.

9.0.1. Sequence of Activities

The various activities required to determine the origin using the scientific method (data collection, analysis, hypothesis development, and hypothesis testing) occur continuously. Likewise, recording the scene, note taking, photography, evidence identification, witness interviews, cause investigation, failure analysis, and other data collection activities may be performed simultaneously with these efforts. Generally, the various activities of origin determination will follow a routine sequence, while the specific actions within each activity may be taking place at the same time.

9.0.2. Sequential Pattern Analysis

The area of origin may be determined by examining the fire effects and fire patterns. The surfaces of the fire scene record all of the fire patterns generated during the lifetime of the event, from ignition through suppression, although these patterns may be altered, obscured, or obliterated after they are produced, by the subsequent growth and spread of the fire. The key to determining the origin of a fire is to determine the sequence in which these patterns were produced. Investigators should strive to identify and collect sequential data and, once collected, organize the information into a sequential format. An important factor in determining the sequence of pattern production is considering whether the pattern can be accounted for in terms of ventilation.

9.0.3. Systematic Procedure

Investigators should establish a systematic procedure to follow for each type of incident. By following a familiar procedure, the investigator can concentrate on the incident at hand and need not dwell on the details of what the next step in the procedure will be. By doing so, the investigator may avoid overlooking significant evidence and will avoid forming premature conclusions about the origin.

9.0.4. Recommended Methodology

This chapter discusses a recommended methodology for the examination of the fire scene. This methodology consists of an initial scene assessment, development of a preliminary fire spread hypothesis, an in-depth examination of the fire scene and reconstruction of the fire scene, development of a final fire spread hypothesis, and identification of the fire's origin. Origin identification may occur earlier in the process, depending on the types and time of arrival of various data. This recommended methodology serves to inform the investigator but is not meant to limit the origin determination to only this procedure. Investigators, within the scope of their investigations, should consider all aspects of the fire event during the investigation. Witness statements, the investigator's expertise, and fire-fighting procedures play important roles in the determination of the fire origin.

9.2. Data Collection for Origin Determination

This section describes the data collection process for origin determination, including initial scene assessment, excavation and reconstruction, and collection of additional data from witnesses and other sources.

9.0.1. Initial Scene Assessment

An initial assessment should be made of the fire scene. As the investigator starts the initial scene assessment, data collection for the determination of the origin begins. Care should be taken during each of the steps within the initial scene assessment to protect the investigator from scene hazards and preserve the scene. The purpose of this initial examination is to determine the scope of the investigation, such as equipment and manpower needed, to determine the safety of the fire scene, and to determine the areas that warrant further study.

9.2.1.1. Safety Assessment

The investigator should first make an initial safety assessment. The investigator should determine if it is safe to enter the scene. If it is not safe to enter, the investigator must determine what steps are required to provide for personal safety or to render the scene safe to enter. Each of the hazards described in Chapter **13** should be assessed. There is no reason the investigator should compromise safety.

9.2.1.2. Scope of the Examination

After safety issues have been addressed, the investigator may begin the initial scene assessment. The purpose of this initial assessment is to determine the complexity and extent of the investigation, identify required equipment and staffing, and determine the areas that warrant further analysis.

9.2.1.3. Order of the Examination

This assessment may take place concurrently with the initial documentation of the scene. The assessment should include an overall look at the entire scene or structure, both exterior and interior, and all pertinent areas. The order in which the assessment takes place may vary, depending on scene conditions. Some investigators prefer to start with the least damaged area and move toward the most damaged area. Some investigators prefer to start at the highest point in a scene and work downward. Whatever order is selected for a particular scene, the point is to assess all areas that are pertinent to the origin and spread of the fire.

9.2.1.4. Surrounding Areas

Investigators should include in their examination the site or areas around the scene. These areas may exhibit significant evidence or fire patterns, away from the main body of the scene that may enable the investigator to better define the site and the investigation. Anything of interest should be documented as to its location in reference to the scene. This phase of the examination can be used to canvass the neighborhood for witnesses to the fire and for persons who could provide information about the incident.

9.2.1.5. Structure Exterior

An inspection of the entire perimeter of the structure may reveal the extent and location of damage and may help determine the size and complexity of the scene. The general construction method and occupancy classification should be noted. The construction refers to how the building was built, types of materials used, exterior surfaces, previous remodeling, and any unusual features that may have affected how the fire began and spread. A significant consideration is the degree of destruction that can occur in a structure consisting of mixed types and methods of construction.

The occupancy classification refers to the current use of the building. Use is defined as the activities conducted and the manner in which such activities are undertaken. The number and circumstances of those individuals occupying the space may also be relevant. If the occupancy classification or use of the structure has changed, this should be considered and noted. Changes in use and occupancy classification sometimes require modifications to the structural, architectural, or fire protection features in accordance with applicable codes. Such modifications may or may not have been undertaken.

The fire damage and evidence of significant smoke, heat, and flame venting on the exterior should be documented and considered to assist in determining those areas that warrant further study. An in-depth examination of fire effects and patterns is not necessary at this point in the investigation.

9.2.1.6. Structure Interior

On the initial assessment, investigators should examine all rooms and other areas that may be relevant to the investigation, including those areas that are fire damaged or adjacent to the fire- and smoke-damaged areas. The primary purpose of this assessment is to identify the areas that need more detailed examination. The investigator should be observant of conditions of occupancy, including methods of storage, nature of contents, housekeeping, and maintenance. The type of construction, interior finish (es), and furnishings should be noted. Areas of damage and extent of damage in each area (e.g., severe, minor, or none) should be noted. The investigator should attempt to identify which compartments became fully involved (i.e., ventilation-controlled) and which did not. This damage should be compared with the damage seen on the exterior. During this examination, the investigator should reassess the soundness of the structure.

9.2.1.7. Post-Fire Alterations

During this assessment, the investigator should document any indication of post-fire alterations. Such alterations may affect the investigator's interpretation of the physical evidence. Alterations may include debris removal or movement, contents removal or movement, electrical service panel alterations, changes in valve positions on automatic sprinkler systems, and changes to fuel gas systems. If alterations are indicated, attempts should be made to contact the person(s) who altered the scene. They should be interviewed as to the extent of the alterations and the documentation they may have of the unaltered site.

At the conclusion of the preliminary scene assessment, the investigator should have determined the safety of the fire scene, the probable staffing and equipment requirements, and the areas around and in the structure that will require a detailed examination. The preliminary scene assessment is an important aspect of the investigation. The investigator should take as much time in this assessment as is needed to make these determinations. Time spent in this endeavor may save significant time and effort in later stages of the investigation.

9.0.2. Excavation and Reconstruction

Fire scene excavation (the examination, layering, and removal of debris) and reconstruction allows the investigator to observe patterns on exposed surfaces and to locate evidence that can assist in making an accurate origin analysis. The purpose of fire scene reconstruction is to recreate as nearly as practicable the pre-fire positions of contents and structural components. Interviews, diagrams, photographs, and other means can be helpful in establishing pre-fire conditions.

9.2.2.1. Scope of Excavation and Reconstruction

Because the preliminary scene assessment has identified the areas warranting further examination, the task of fire scene reconstruction may not necessitate the removal of debris and the replacement of the conte ucture. The preliminary scene assessment should not be done hastily nts throughout the entire str *(see* ***<u>18.3.1.8</u>****)*. Careful analysis of the fire scene may help to reduce to a practical level the strenuous task of debris removal. If the area to be reconstructed cannot be reduced, then the investigator should accept the necessity of removing the debris from the entire area of interest. *(See* ***<u>Figure 18.3.2.1</u>****.)*

Figure 18.3.2.1 Walls and Ceiling Reconstructed on Floor to Observe Patterns.

9.2.2.2. Safety

Safe work practices throughout this effort are required. Debris excavation and removal can weaken a structure and cause it to collapse. Debris removal can also expose hazardous substances, uncover holes in the floor, and can expose energized electrical wiring. All significant risks that may be encountered during an investigation should be minimized before the investigation continues. See Chapter **13** for a detailed discussion on safety.

9.2.2.3. Excavation

Adequate debris removal is essential for a thorough fire investigation. Inadequate removal of debris and the resultant exposure of limited portions of the fire patterns and other evidence may lead to an incorrect analysis. A fire scene investigation normally involves dirty and strenuous work. Acceptance of this fact is essential in conducting a proper fire investigation.

The removal of debris during the overhaul stage of fire suppression operations is an area of concern for the fire investigator. Firefighters may disturb the scene, thus making origin determination more difficult. Only those overhaul and suppression operations necessary to ensure complete extinguishment should be conducted. When these operations call for substantial scene alterations, an attempt should be made to document the fire scene with photography and notes prior to the alterations, if practical.

Investigators should consider where debris will be placed during removal. In some instances, it may be desirable to move the debris to a secure location. Debris should only be moved to an area that has already been examined or has no future need for examination or documentation. Moving debris twice is counterproductive. Debris removal should be performed in a planned and systematic fashion. This means that debris should be removed in layers, with adequate documentation as the process continues. If more than one investigator is doing the removal, they should discuss the purpose for the debris removal prior to starting. A discussion may prevent one investigator from discarding something the other investigator considers important. Each layer should be examined for significant artifacts as the debris is being removed.

During the excavation of a scene there exists a danger of evidence destruction. Although it is desirable to work efficiently, the use of heavy equipment to remove debris should only be undertaken if it is not practical to use hand tools to accomplish the task. Inappropriate use of mechanized excavating equipment can potentially destroy more evidence than it reveals.

9.2.2.4. Heavy Equipment

An investigation may require the use of heavy equipment such as cranes, backhoes, or front-end loaders. The condition of the fire scene may necessitate removal of building components or contents, because they constitute a safety hazard, are blocking access, or need to be removed during the systematic examination of the scene. Before using heavy equipment, the scene should be documented in the same manner as in all investigations. Documentation should also be conducted at frequent intervals when heavy equipment is being used.

Working with heavy equipment can be dangerous and noisy. One investigator should be appointed to communicate with the heavy equipment operator. A briefing session including the goals for this section should be held with the crew/operator as the investigation advances into new physical areas. The speed at which fire investigations occur is substantially slower than the ordinary speed at which heavy equipment operates. A commonly understood set of hand signals should be confirmed before beginning to use heavy equipment so that the crew/operator is clear from where direction comes and about the meaning of hand signals indicating specific actions. To reduce the risk of personal injury, the operation of heavy equipment should cease whenever a person enters the area of hazard where the machine is operating.

Prior to the use of heavy equipment, areas where the presence of ignitible liquid residue is suspected should be identified, if practicable. When possible, the samples should be collected prior to the use of equipment in those areas. Prior to use, heavy equipment should be inspected and any leaks of petroleum products should be noted. Fueling of the equipment should occur in a designated area, removed from the areas of interest, that will not contaminate the scene or items entering the scene. If contamination is of concern, samples of the equipment fluids should be collected for comparison purposes.

It is preferable to utilize the heavy equipment in a manner that has the least impact on the scene. The least destruction is usually accomplished by positioning the equipment outside the building and using the equipment to lift or move items from the inside to the outside of the building. When lifting a potential piece of evidence, rigging can be used to minimize damage to the removed item. If large components such as walls need to be demolished, it is preferable to do so in a manner that does not change or add debris to the underlying area to be examined. Safety concerns and site constraints can preclude this practice. Shoring should be considered as an alternative to demolition when possible and appropriate.

Items that are removed from the building can be examined and documented, and can remain at the fire scene if needed for further investigation. The removal of debris offsite can limit further investigation, but is sometimes necessary. Removal off site should be well documented.

Some investigations will require the use of heavy equipment inside the scene. In such cases, equipment should be used in a manner that is the least disruptive of the scene. One method involves using the equipment to systematically progress into a building. The equipment is initially positioned outside the building and used to aid the examination of a portion of the interior of the building. Once that area is examined, documented, and the debris removed, the heavy equipment is brought onto that cleared location. From that new position, the equipment is used to aid in the examination of adjacent areas. This progression is repeated as many times as needed. At all times, the equipment is only located in areas that have been previously examined and documented. At all times, the equipment operator should be under the direction of a fire investigator. The collection and unloading of each load should be observed for relevant evidence. Preplanning the progression of the examination can help to limit unnecessary alteration of the scene.

9.2.2.5. Avoiding Spoliation

During the excavation, care should be taken to avoid damaging ignition sources, fuels, or other potentially important evidence within the scene. If the investigator's area of interest contains important evidence, consideration should be given to suspending the investigation and putting potentially interested parties on notice, to give them an opportunity to see the evidence in place.

9.2.2.6. Avoiding Contamination

To avoid scene contamination, extreme care should be taken with respect to the use of portable liquid-fueled equipment, such as gasoline-powered saws. Re-fueling of such equipment should be done away from the structure.

9.2.2.7. Washing Floors

After adequate debris removal has occurred, necessary samples have been taken for examination or testing, and proper scene documentation is completed, it may be useful to flush the floor or surface with water. This flushing may help to better reveal fire patterns. The use of high pressure and straight streams should be used with caution because such activities may harm significant evidence. *[See **Figure 18.3.2.7(a)** and **Figure 18.3.2.7(b)**.]*

Figure 18.3.2.7(a) Washing Floors May Assist in Identifying Patterns: View One.

Figure 18.3.2.7(b) Washing Floors May Assist in Identifying Patterns: View two.

9.2.2.8. Contents

Any contents, or their remains, uncovered during debris removal should be documented as to their location, condition, and orientation. Once the debris has been removed, the contents can be placed in their pre-fire positions for analysis.

When the contents have been displaced during fire suppression or overhaul, post-fire reconstruction becomes much more difficult. The position where the item was located may exhibit a protected area or other indicator from the item, such as table legs leaving small clear spots on the floor. The problem is knowing which leg goes to which spot. If a definite determination is not possible by scene analysis or witness identification, then all potential orientations should be considered. Otherwise, the orientation should not be included in the fire scene reconstruction. A guess as to how contents were oriented may be wrong, thereby contributing false data to the analysis process. An alternative is to document the contents in all probable positions in the hope that later information will pinpoint the accurate location.

In addition to the replacement of contents, reconstruction may also include the replacement of structural elements (e.g., doors, joists, studs, sections of walls and floors) that may have recorded fire patterns.

9.0.3. Additional Data Collection Activities for Origin Determination

The following paragraphs describe activities in addition to the scene examination and reconstruction, which will lead to the development of data useful in the determination of the origin.

9.2.3.1. Pre-Fire Conditions

The pre-fire conditions of the structure should be determined to the extent practicable. Details such as the state of repair, condition of foundations and chimneys, insect damage, the presence and condition of fire protection systems, and so forth may prove to be significant data. Obtaining pre-fire photographs or video may be beneficial, but be aware that changes may have occurred between the time the photograph was taken and the time of the fire. Owners, employees, or occupants may be able to provide information and diagrams of pre-fire conditions. Checking with neighbors may also provide photographs showing the structure. Some jurisdictions now offer pre-fire photographs of the structure on tax record websites. There are companies specializing in aerial photography, primarily of commercial structures, which may offer pre-fire views. Satellite images are also available for many areas and may offer pre-fire documentation of both the site and the surrounding area. Additional information may be available from the fire department, which could include photographs, structure diagrams, special hazards, and fire protection systems. Other government agencies may also have pre-fire information and records.

9.2.3.2. Description of Fuels

The investigator should identify the fuels present in the building or area of interest and the characteristics of those fuels. When considering the area of origin, the type, quantity, and specific location of structural and content fuels should be identified to assist in the analysis of the fire patterns, fire growth, and spread characteristics. In this process, it is not only important to identify the potential first fuel ignited, but also to identify subsequent fuels involved.

9.2.3.3. Structure Dimensions

The physical dimensions of a structure are important data. In many instances, the post-fire structure provides the only means of obtaining dimensions. Dimensions should be recorded for all areas of the structure that may be used to understand fire growth, and smoke and fire spread. Dimensions should include the width, length, and height of a room or structure. The location, size, and condition (opened/closed) of all openings should be recorded, as well as any structures or obstructions that would affect the flow of fire gases. The effort associated with obtaining the dimensions can be time consuming and the amount of information collected may be limited depending on the extent of destruction. Specific dimensional information is necessary to reconstruct the fire event via a fire model or hand calculations *(**see Chapter 21**)*. When the scene is no longer available, information may be obtained from the investigative photographs, notes and diagrams of previous investigators, or from architects, engineers, contractors, insurance companies, or government offices such as building departments. The investigator should assess the accuracy of the plans and whether the plans actually represent the "as-built" structure. *(See the discussion of building design in **7.2.2.6**.)*

9.2.3.4. Weather Conditions

The investigator should document weather factors that may have influenced the fire. The surrounding area may provide evidence of the weather conditions. Wind direction may be indicated by smoke movement or by fire damage sustained by structures or vegetation. Additionally, post-fire weather may cause changes to the physical condition of the scene.

9.2.3.5. Electrical Systems

The electrical system should be documented. The means used to distribute electricity should be determined, and damage to the systems should be documented. The documentation process should begin with the incoming electrical service. The main panel amperage and voltage input should be noted. The type, rating, position (on/tripped/off), and condition of the circuit protection devices may be relevant to the investigation and should be documented.

9.2.3.6. Electrical Loads

Note the location of electrical receptacles and switches within the room or area of origin. Electrical items plugged into the receptacles should be identified and documented. The investigative process may involve the tracing of circuits throughout a structure. The purpose for tracing these circuits is to identify the switches, receptacles, and fixtures on a particular circuit, as well as which over-current device protects that circuit, and its position and condition. Electrical appliances and loads should be noted. A more detailed documentation of electrical systems and devices may be necessary where they are believed to be the fire cause or a contributing factor, or when arc mapping is used. Use caution when interpreting damage to electrical wiring and equipment because it may be difficult to distinguish cause from effect. For a more detailed explanation of electrical systems, see Chapter **9**.

9.2.3.7. HVAC Systems

The air movement through HVAC systems can affect the growth and spread of a fire and can transport combustion products throughout a structure. The investigator should record the location, size, and function (supply/return/exhaust) of vents in the area of interest, and whether the vent was open, closed, or covered at the time of the fire. Checking filters may provide evidence of heat or smoke damage and soot deposition to determine whether the HVAC system was operating at the time of the fire. Some HVAC systems are equipped with detectors designed to change the operation of the system in case of fire. Some systems are equipped with manual or automatic dampers designed to control fire spread, smoke movement, or airflow. Where these devices are present, their specific location and condition should be noted and any activation records should be obtained. The location and setting of any thermostats, switches, or controls for the HVAC system should be identified and documented.

9.2.3.8. Fuel Gas Systems

The fuel gas supply should be identified and documented. The purpose of this examination is to assist in determining whether the fuel gas contributed to the fire. If the examination reveals that fuel gases may have been a contributing factor, then the system should be examined and documented in detail. This examination should include testing for leaks, if possible, and determining the supply pressure, if possible. As with electrical systems, it may be difficult to distinguish between evidence of cause and effect. Fires can, and frequently do, compromise the integrity of gas distribution systems. The investigator should document the condition and position (open/closed) of system valves. Valves are frequently turned off during fires, so an attempt should be made to ascertain if anyone operated any valves during the event.

9.2.3.9. Liquid Fuel Systems

A variety of liquid fuel systems and appliances exists. These may be permanent systems, such as oil-fired space heaters and water heaters, or portable systems, such as kerosene or white gas heaters. In either case, the location and quantity of fuel present should be documented. Supply lines and valves to connected fuel supplies in remote tanks should also be documented. If the device contains an attached or integral tank, the amount of fuel remaining in the device should be estimated or measured. If the heating device is a suspected cause, or its fuel is believed to have contributed to the spread of the fire, a sample of the fuel should be preserved.

9.2.3.10. Fire Protection Systems

The examination of all involved fire protection systems (fire detection, fire alarm, and fire suppression systems) is important in determining if each system functioned properly, and can assist in tracking the growth and spread of a fire. If the system was monitored, records should be obtained from the monitoring service. In some instances, information can be downloaded from the central panel to indicate alarm and trouble signal locations and times. This is volatile data and care must be taken in extracting it from the alarm panel. Extracting this data generally requires specific knowledge and equipment. A qualified technician should be employed for downloading the data as substantial permanent loss of data can occur if this is done incorrectly. In many cases, building electrical power may be discontinued after a fire so that a limited amount of time is available for recovering the data while the system is operating on its backup battery. This limited time window should be taken into account when ordering scene activities.

9.2.3.11. Fire Protection System Data

Device locations and conditions should be documented, including the height of wall-mounted devices or the distance of ceiling-mounted devices from walls. Which sprinklers activated should be considered when examining fire spread patterns. Both detector activation and sprinkler activation may provide sequential data. In some cases, the specific location or zone of the first activating detector or sprinkler can be used to narrow down an area of origin, allowing an investigator to assess specific ignition sources in that area. Some systems provide only alarm or water flow data, and do not specify a particular zone. This information can be helpful in comparing the time of system activation to the time and observations of first arriving fire fighters or other witness, in assessment of the growth and spread of the fire.

9.2.3.12. Security Cameras

Security cameras that monitor buildings or ATMs may be very useful, particularly for providing “hard” times *(see the discussion of timelines in **Chapter 24**)***.** Events before or during the fire including, in some cases, the actual ignition and development of the fire may have been recorded. The video recorder may be found in a secure area or a remote location. It should be recovered and reviewed even if damaged.

9.2.3.13. Intrusion Alarm Systems

An intrusion system may activate during a fire due to heat, smoke movement, the destruction of wiring, or loss of power. A monitored intrusion system may send a trouble signal to the monitoring station if a transmission line is compromised or power is lost. As with fire alarm systems, attempts should be made to recover the alarm panel history before the alarm system is reset. This frequently requires special expertise. Some alarm systems may record the identity of persons entering and leaving the building.

9.2.3.14. Witness Observations

Observations by witnesses are data that can be used in the context of determining the origin. Such witnesses can provide knowledge of conditions prior to, during, and after the fire event. Witnesses may be able to provide photographs or videotapes of the scene before or during the fire. Observations are not necessarily limited to visual observations. Sounds, smells, and perceptions of heat may shed light on the origin. Witness statements regarding the location of the origin create a need for the fire investigator to conduct as thorough an investigation as possible to collect data that can support or refute the witness statements. When witness statements are not supported by the investigator's interpretation of the physical evidence, the investigator should evaluate each separately.

9.3. Analyze the Data

The scientific method requires that all data collected that bears upon the origin be analyzed. This is an essential step that must take place before the formation of any hypotheses. The identification, gathering, and cataloging of data does not equate to data analysis. Analysis of the data is based on the knowledge, training, experience, and expertise of the individual doing the analysis. If the investigator lacks the knowledge to properly attribute meaning to a piece of data, then assistance should be sought from someone with the necessary knowledge. Understanding the meaning of the data will enable the investigator to form hypotheses based on the evidence, rather than on speculation or subjective belief.

9.0.1. Fire Pattern Analysis

An investigator should read and understand the concepts of fire effects, fire dynamics, and fire pattern development described in Chapters 5 and 6. This knowledge is essential in the analysis of a scene to determine the origin of the fire.

9.3.1.1. Consideration of All Patterns

All observed patterns should be considered in the analysis. Accurate determination of the origin of a fire by a single dominant fire pattern is rare, as in the case of very limited fire damage where there may be only one fire pattern.

9.3.1.2. Sequence of Patterns

While fire patterns may be the most readily available data for origin determination, the investigator should keep in mind that the damage and burn patterns observed after a fire represent the total history of the fire. A major challenge in the analysis of fire pattern data is to determine the sequence of pattern formation. Patterns observed in fires that are extinguished early in their development can present different data than those remaining after full room involvement or significant building destruction. Patterns generated as a result of a rekindle may impact the perception of the fire's history or sequence of pattern production.

9.3.1.3. Pattern Generation

The investigator should not assume that the fire at the origin burned the longest and therefore fire patterns showing the greatest damage must be at the area of origin. Greater damage in one place than in another may be the result of differences in thermal exposure due to differences in fuel loading, the location of the fuel package in the compartment, increased ventilation, or fire-fighting tactics. For similar reasons, a fire investigator should consider these factors when there is a possibility of multiple origins.

The size, location, and heat release rate of a fuel package may have as much effect on the extent of damage as the length of time the fuel package was burning. An area of extensive damage may simply mean that there was a significant fuel package at that location. The investigator should consider whether the fire at such a location might have spread there from another location where the fuel load was smaller.

Fuel packages of identical composition and equal size may burn very differently, depending on their location in a compartment. The possible effect of the location of walls relative to the fire should be considered in interpreting the extent of damage as it relates to fire origin. In making the determination, the possibility that the fuel in the suspected area of origin was not the first material ignited and that the great degree of damage was the result of wall or corner effects should be considered.

9.3.1.4. Ventilation

Ventilation, or lack thereof, during a fire has a significant impact on the heat release rate and consequently on the extent of observable burn damage. The analysis of fire pattern data should, therefore, include consideration that ventilation influenced the production of the pattern. Ventilation-controlled fires tend to burn more intensely near open windows or other vents, thereby producing greater damage. Knowledge of the location and type of fuel is important in fire pattern analysis. During full room involvement conditions, the development of fire patterns is significantly influenced by ventilation. Full room involvement conditions can cause fire patterns that developed during the earlier fuel-controlled phase of the fire to evolve and change. In addition, fires can produce unburned hydrocarbons that can be driven outside the compartment through ventilation openings. This unburned fuel can mix with air and burn on the exterior of the compartment, producing additional fire patterns that indicate the fire spread out of the original compartment. Thus, knowledge of changes in ventilation (e.g., forced ventilation from building systems, window breakage, opening or closing of doors, burn-through of compartment boundaries) is important to understand in the context of fire pattern analysis. Determination of what patterns were produced at the point of origin by the first item ignited usually becomes more difficult as the size and duration of the fire increases. This is especially true if the compartment has achieved full room involvement.

9.3.1.5. Movement and Intensity Patterns

As discussed in Chapter **6**, fire patterns are generated by one of two mechanisms: the spread of the fire or the intensity of burning. As discussed above, fuel composition, rate of heat release, location, and ventilation differences may lead to differences in the intensity patterns that do not necessarily point to the area where the first fuel was ignited. Patterns that arise from the growth and movement (spread) of the fire are invariably better indicators of the area of origin. It may be difficult, however, to distinguish movement patterns from intensity patterns. Further, some patterns display a combination of intensity and movement (spread) indicators.

Fire patterns should be evaluated to determine whether it can be accounted for in terms of ventilation. Ventilation-generated patterns may not be produced early in the fire. Patterns that cannot be accounted for in terms of ventilation are the patterns that need careful examination.

9.0.2. Heat and Flame Vector Analysis

Heat and flame vector analysis, along with accompanying diagram(s), is a tool for fire pattern analysis. Heat and flame vectoring is applied by constructing a diagram of the scene. The diagram should include walls, doorways and doors, windows, and any pertinent furnishings or contents. Then, through the use of arrows, the investigator notes the interpretations of the direction of heat or flame spread based upon the identifiable fire patterns present. The size of the arrows should reflect the scaled magnitude (actual size) of the individual patterns depicted. The arrows can point in the direction of fire travel from the heat source, or point back toward the heat source, as long as the direction of the vectors is consistent throughout the diagram. The investigator should identify each vector as to the respective fire pattern it represents. In a legend accompanying the diagram the investigator may give details of the corresponding fire pattern, such as height above the floor, height of the vertex of the pattern, the nature of the surface upon which the pattern appears, the pattern geometry, the particular fire effect which constitutes the pattern, and the direction(s) of fire spread which the pattern(s) represent. For example, as shown in **Figure 18.4.2(a)** through **Figure 18.4.2(f)**, Vector #7 represents burn damage on the carpet with decreasing fire damage as one moves northeast, Vector #8 represents comparison of the burn damage differences between the two sides of the chair with the south side displaying more severe damage, and Vector #10 represents a truncated cone pattern with decreasing fire damage and increasing height to the line of demarcation as one moves north.

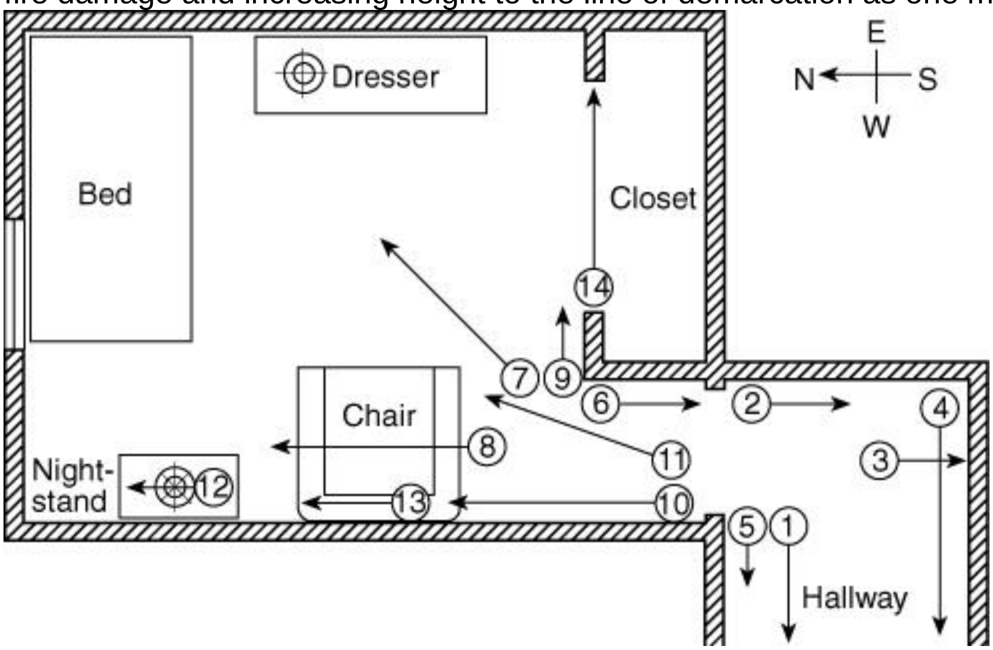


Figure 18.4.2(a) Heat and Flame Vector Analysis Diagram Associated Vectors of the

Physical Size and Direction of Heat Travel of the Fire Patterns and Demonstrating a Fire Origin in the Area of Vectors 7, 8, and 10.

Figure 18.4.2(b) Photograph associated with Vector #7.

Figure 18.4.2(c) Photograph associated with Vector #8.

Figure 18.4.2(d) Photograph associated with Vector #10.

Figure 18.4.2(e) Photograph associated with Vector #11.

Figure 18.4.2(f) Photograph associated with Vector #6.

9.3.2.1. Complementary Vectors

Complementary vectors can be considered together to show actual heat and flame spread directions. In that case, the investigator should clearly identify which vectors represent actual fire patterns and which vectors represent heat flow derived from the investigator's analysis of these patterns. An important point to be made regarding this discussion is the terminology *heat source* and *source of heat*. These terms are not synonymous with the origin of the fire. Instead, these terms relate to any heat source that creates an identifiable fire pattern. The heat source may or may not be generated by the first fuel ignited. It is imperative that the use of heat and flame vector analysis be tempered by an accurate understanding of the progress of the fire and basic fire dynamics. A vector diagram can give the investigator an overall viewpoint to analyze. The diagram can also be used to identify any conflicting patterns that need to be explained. The ultimate purpose of the vector analysis is to discuss and graphically document the investigator's interpretation of the fire patterns.

9.3.2.2. Heat Source

A heat source can be any fuel package that creates an identifiable fire pattern. The pattern may or may not be produced by the first fuel ignited. Consider a fire that spreads into a garage and ignites flammable liquids stored there. The burning liquid represents a new heat source that leaves fire patterns on the garage's surfaces. Therefore, it is imperative that fire pattern analysis be tempered by an accurate understanding of the progress of the fire and basic fire dynamics.

9.3.2.3. Additional Tools for Pattern Visualization

When fire patterns are not visually obvious, a depth of char or depth of calcination survey may help the investigator to locate areas of greater or lesser heat damage and recognized lines of demarcation defining patterns. Survey results should be plotted on a diagram. On such diagrams, the depth of char or calcination measurements are recorded to a convenient scale. Once the depth of char or calcination measurements have been recorded on the diagram, lines can be drawn connecting points of equal, or nearly equal, char or calcination depths. The resulting lines may reveal identifiable patterns. *[See **Figure 16.4.2(f)**.]*

9.0.3. Analysis of Sequential Events

The analysis of the timing or sequence of events during a fire can be useful in determining the origin. Much of the data for this analysis will come from witnesses. In some instances, a witness may be found who saw the fire in its incipient stage and can provide the investigator with an area of fire origin. Such circumstances create a burden on the fire investigator to conduct as thorough an investigation as possible to find facts that can support or refute the witness's statements. Means to verify such statements could include patterns analysis, arc mapping, or matching smoke alarm, smoke detector, heat detector, and security detector activation times with the witness's observations. This analysis can identify gaps or inconsistencies in information, assist in developing questions for additional witness interviews, and provide support in the analysis and reconstruction of the progression of the fire. A more detailed discussion of time lines is included in Section **21.2**.

9.0.4. Fire Dynamics

Fundamentals of fire dynamics can be used to analyze the data to aid in the development of origin hypotheses and to complement other origin determination techniques. Such analyses can help in the identification of potential fuels that may have been the first item to ignite, the sequence of subsequent fuel involvement, the recognition of other data that may need to be collected, the analysis of fire patterns, and the identification of potential competent ignition sources.

One of the most important fire dynamics considerations is the availability of oxygen. If the area of origin becomes oxygen deprived as a result of full room involvement, there may be less damage around the origin than elsewhere. The most damaged areas may have been damaged solely as a result of increased ventilation that occurred late in the fire. Basing an origin determination solely on the degree of damage has led to erroneous origin determinations in test fires.

One tool a fire investigator may consider to account for the history of the various fire patterns observed is to divide each compartment into volumes, and then consider the extent of the damage expected before and at flashover, a short time after flashover, and a long time after flashover, given an origin in each of the volumes. This analysis has been called an origin matrix analysis.

9.0.5. Origin Matrix Analysis

Figure A.18.4.5.1 is an example of the origin matrix analysis applied to a simple rectangular room with a single ventilation opening. Consideration of the fire patterns alone may be of limited assistance in determining the origin in the case of a fire that burns for a long duration after full room involvement. Damages resulting from ventilation-related fire exposures may create new patterns that may eventually obscure or obliterate origin-related fire patterns. However, origin-related damages located remotely from ventilation-related fire exposures may persist. In a general sense, timing cannot be quantified beyond “short” and “long” durations as indicated by **Figure A.18.4.5.1** because they will ultimately be scenario dependent.

Multiple ventilation openings can complicate an origin matrix analysis, as can consideration of an origin locate above floor level, such as on a stovetop. *(See **5.10.3**.)*

9.4. Developing Origin Hypotheses

Based on the data analysis, the investigator should now produce a hypothesis or group of hypotheses to explain the origin and development of the fire. This hypothesis should be based solely on the empirical data that the investigator has collected. It is understood that when using the scientific method, an investigator may continuously be engaged in data collection, data analysis, hypothesis development, and hypothesis testing. An investigator may develop an origin hypothesis early in the investigative process, but when the process is completed, regardless of the order of steps followed, the investigator should be able to describe how those steps conform to the scientific method. **Figure 18.2** shows how the procedures set forth in this chapter follow the scientific method.

9.0.1. Initial Hypothesis

The initial origin hypothesis is developed by considering witness observations, by conducting an initial scene assessment, and by attempting to explain the fire's movement through the structure. This process is accomplished using the methods described in earlier sections of this chapter. The initial hypothesis allows the investigator to organize and plan the remainder of the origin investigation. The development of the initial hypothesis is a critical point in the investigation. It is important at this stage that the investigator attempt to identify other feasible origins, and to keep all reasonable origin hypotheses under consideration until sufficient evidence is developed to justify discarding them.

9.0.2. Modifying the Initial Hypothesis

The investigation should not be planned solely to prove the initial hypothesis. It is important to maintain an open mind. The investigative effort may cause the initial hypothesis to change many times before the investigation is complete. The investigator should continue to reevaluate potential areas of origin by considering the additional data accumulated as the investigation progresses.

9.5. Testing an Origin Hypothesis for Validity

In order to conform to the scientific method, once a hypothesis is developed, the investigator must test it using deductive reasoning. A test using deductive reasoning is based on the premise that *if* the hypothesis is true, *then* the fire scene should exhibit certain characteristics, assuming that the fire did not subsequently obliterate those characteristics. For example, if a witness stated that a specific door was closed during the fire, then there should be a protected area on the door jamb, which would tend to prove the hypothesis that the door was closed. *(See Chapter* ***4*** *and* ***A.4.3.6****.)*

9.0.1. Means of Hypothesis Testing

During the investigation, the investigator may develop and test many hypotheses about the progress of the fire. For example, the investigator often has to determine whether a door or window was open or closed. Ultimately, the origin determination is arrived at through the testing of origin hypotheses. A technically valid origin determination is one that is uniquely consistent with the available data. In testing the hypothesis, the questions addressed in **18.6.1.1** through **18.6.1.3** should be answered.

Is there a competent ignition source at the hypothetical origin? The lack of a competent ignition source at the hypothesized origin should make the hypothesis subject to increased scrutiny. Investigators should be wary of the trap of circular logic. While the cause of the fire was at one time necessarily located at the point of origin, the investigator who eliminates a potential ignition source because it is "not in the area of the hypothesized origin," needs to be especially diligent in testing the origin hypothesis and in considering alternate hypotheses. *(See Section **19.2**.)* This is particularly true in cases of full room involvement. Unless there is reliable evidence to narrow the origin to a particular portion of the room, every potential ignition source in the compartment of origin should be given consideration as a possible cause.

Can a fire starting at the hypothetical origin result in the observed damage? The investigator should be cautious about deciding on an origin just because a readily ignitible fuel and potential ignition source are present. The sequence of events that bring the ignition source and the fuel together and cause the observed damage indicates the origin, and ultimately the cause. The hypothetical origin should not only account for physical damage to the structure and contents, but also for the exposure of occupants to the fire environment.

Is the growth and development of a fire starting at the hypothetical origin consistent with available data at a specific point(s) in time? Few data are more damaging to an origin hypothesis than a contradictory observation by a credible eyewitness. Any data can be contradictory to the ultimate hypothesis. The data must be taken as a whole in considering the hypothesis, with each piece of data being analyzed for its reliability and value. Ultimately, the investigator should be able to explain how the growth and development of a fire, starting at the hypothesized origin, is consistent with the data.

9.0.2. Analytical Techniques and Tools

Analysis techniques and tools are available to test origin hypotheses. Using such tools and techniques to analyze the dynamics of the fire can provide an understanding of the fire that can enhance the technical basis for origin determinations. Such analyses can also identify gaps or inconsistencies in the data. The utility of fire dynamics tools is not limited to hypothesis testing. They may also be used for data analysis and hypothesis development. Techniques and tools include time line analysis, fire dynamics analysis, and experimentation.

9.5.2.1. Time Line Analysis

Time lines are an investigative tool that can show relationships between events and conditions associated with the fire. These events and conditions are generally time-dependent, and thus, the sequence of events can be used for testing origin hypotheses. Relevant events and conditions include ignition of additional fuel packages, changes in ventilation, activation of heat and smoke detectors, flashover, window breakage, and fire spread to adjacent compartments. Much of this information will come from witnesses. Fire dynamics analytical tools *(see* ***21.4.8****)* can be used to estimate time-dependent events and fire conditions. A more detailed discussion of time lines is included in Section **21.2**.

9.5.2.2. Fire Modeling

Fundamentals of fire dynamics can be used to test hypotheses regarding fire origin. Such fundamentals are described in the available scientific literature and are incorporated into fire models ranging from simple algebraic equations to more complex computer fire models *(see* ***21.4.8****)*. The models use incident-specific data to predict the fire environment given a proposed hypothesis. The results can be compared to physical and eyewitness evidence to test the origin hypothesis. Models can address issues related to fire development, spread, and occupant exposure.

9.5.2.3. Experimental Testing

Experimental testing can be conducted to test origin hypotheses. If the experimental testing results are substantially similar to the damage at the scene, the experimental data can be said to be consistent with the origin hypothesis. If the experimental testing produces results that are not substantially similar with the damage, an alternative origin hypothesis or additional data may need to be considered, taking into account potential differences between the experimental testing and the actual fire conditions. The following is an example of such an experiment. The hypothesized origin is a wicker basket located in the corner of a wood-paneled room. The data from the actual fire shows the partial remains of the wicker basket, undamaged carpet in the corner, and wood paneling still intact in the corner. A fire test replicating the hypothesized origin totally consumes the carpet, the wicker basket, and the wood paneling. Thus (assuming the test replicated the pre-fire conditions), testing revealed that this hypothesized origin is inconsistent with the damage that would be expected from such a fire.

9.6. Selecting the Final Hypothesis

Once the hypotheses regarding the origin of the fire have been tested, the investigator should review the entire process, to ensure that all credible data are accounted for and all credible alternate origin hypotheses have been considered and eliminated. When using the scientific method, the failure to consider alternate hypotheses is a serious error. A critical question to be answered by fire investigators is, "Are there any other origin hypotheses that are consistent with the data?” The investigator should document the facts that support the origin determination to the exclusion of all other potential origins.

9.0.1. Defining the Area of Origin

Although *area of origin* is common terminology used to describe the origin, the investigator should describe it in terms of the three-dimensional space where the fire began, including the boundaries of that space.

9.0.2. Inconsistent Data

It is unusual for a hypothesis to be totally consistent with all of the data. Each piece of data should be analyzed for its reliability and value — not all data in an analysis has the same value. Frequently, some fire pattern or witness statement will provide data that appears to be inconsistent. Contradictory data should be recognized and resolved. Incomplete data may make this difficult or impossible. If resolution is not possible, then the origin hypothesis should be re-evaluated.

9.0.3. Case File Review

Other investigators can assist in the evaluation of the origin hypothesis. An investigator should be able to provide the data and analyses to another investigator, who should be able to reach the same conclusion as to the origin. Review by other investigators is almost certain to happen in any significant fire case. Differences in opinions may arise from the weight given to certain data by different investigators or the application of differing theoretical explanations (fire dynamics) to the underlying facts in a particular case.

9.7. Origin Insufficiently Defined

There are occasions when it is not possible to form a testable hypothesis defining an area that is useful for identifying potential causes. The goal of origin investigation is to identify the precise location where the fire began. In practice, the investigator has an origin hypothesis when first arriving at a fire scene. The origin is the scene. Sometimes, it is not possible to find an area or volume that is any smaller than the entire scene. Thus, a conclusion of the origin investigation can be the identification of a volume of space too large to identify causal factors, or where no practical boundaries can be established around the volume of the origin. An example of such an origin can be a building that has been totally burned, with no eyewitnesses. Such fires are sometimes called total burns. The area of origin is the building, but in reality, no further testable origin hypothesis can be developed because there is insufficient reliable data.

9.0.1. Large Area Adequate for Determination

There are cases in which a lack of an origin determination does not necessarily hinder the investigation. An example is a case in which a fire resulted from the ignition of fuel gas vapors inside a structure. The resulting damage may preclude the defining of the location where the fuel combined with the ignition source. However, probable ignition sources may still be hypothesized.

9.0.2. Justification of a Large Area of Origin

The origin analysis should identify the data that justify the conclusion that the area of fire origin cannot be reduced to a practical size. Examples of such data could include establishing the fact that there were no significant patterns to trace, that most or all combustible materials were consumed, or that other methods of origin determination were attempted but no reasonable conclusion could be established.

9.0.3. Eyewitness Evidence of Origin Area

If the origin is too large to be useful, then the determination of the fire's cause may become very difficult, or impossible. In some instances, where no further testable origin hypothesis can be developed by examination of the scene alone, a witness may be found who saw the fire in its incipient stage and can provide the investigator with an area of fire origin.

CHAPTER TEN

10.0. FIRE CAUSE DETERMINATION

This chapter recommends a methodology to follow in determining the fire cause. Fire ca use determination is the process of identifying the first fuel ignited, the ignition source, the oxidizing agent, and the circumstances that resulted in the fire. Fire cause determination generally follows origin determination *(see Chapter **18**)*. Generally, a fire cause determination can be considered reliable only if the origin has been correctly determined.

10.0.1. Fire Cause Factors

The determination of the 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, such as failures or human actions, that allowed the factors to come together and start the fire. Device or appliance failures can involve, for example, a high-temperature thermostat that fails to operate. The device may have failed due to a design defect. Human contributions to a fire can include a failure to monitor a cooking pot on the stove, failure to connect electrical wiring tightly resulting in a high-resistance connection, or intentional acts. For example, consider a fire that starts when a blanket is ignited by an incandescent lamp in a closet. The various factors include having a lamp hanging down too close to the shelf, putting combustibles too close to the lamp, and leaving the lamp on while not using the closet. The absence of any one of those factors would have prevented the fire. The function of the investigator is to identify those factors that contribute to the fire.

10.0.2. First Fuel Ignited

The first fuel ignited is that which first sustains combustion beyond the ignition source. For example, the wood of the match would not be the first fuel ignited, but paper, ignitible liquid, or draperies would be, if the match were used to ignite them.

10.0.3. Ignition Source

The ignition source will be at or near the point of origin at the time of ignition, although in some circumstances, such as the ignition of flammable vapors or in circumstances involving remote ignition, such as from convection or radiation, the two may not appear to coincide. Sometimes the source of ignition will remain at the point of origin in recognizable form, whereas other times the ignition source may be altered, destroyed, consumed, moved, or removed. Nevertheless, the ignition source should be identified in order to determine the fire cause. However, in instances involving remote ignition, there will be no physical evidence of an ignition source at a hypothetical origin *(see **5.9.2.2**)*. In instances such as these, the source of ignition and ignition sequence can be hypothesized based on other data.

10.0.4. Oxidant

Generally, the oxidant is the oxygen in the earth's atmosphere. Medical oxygen, such as that stored in cylinders or produced by oxygen concentrators, and certain chemical compounds may support or enhance combustion reactions *(see **5.1.5.2**)*.

10.0.5. Ignition Sequence

A fuel by itself or an ignition source by itself does not create a fire. Fire results from the combination of fuel, an oxidant, and an ignition source. The investigator's description of events, including the ignition sequence (the factors that allowed the ignition source, fuel, and oxidant to react), can help establish the fire cause.

10.1. Overall Methodology

The overall methodology for determining the fire cause is the scientific method as described in Chapter **4**. This methodology includes recognizing and defining the problem to be solved, collecting data, analyzing the data, developing a hypothesis or hypotheses, and, most importantly, testing the hypothesis or hypotheses. In order to use the scientific method, the investigator must develop at least one hypothesis based on the data available at the time. These initial hypotheses should be considered "working hypotheses," which upon testing may be removed from further consideration, revised, or expanded in detail as new data is collected during the investigation and new analyses are applied. This process is repeated as new information becomes available. *(See **Figure 19.2**.)*

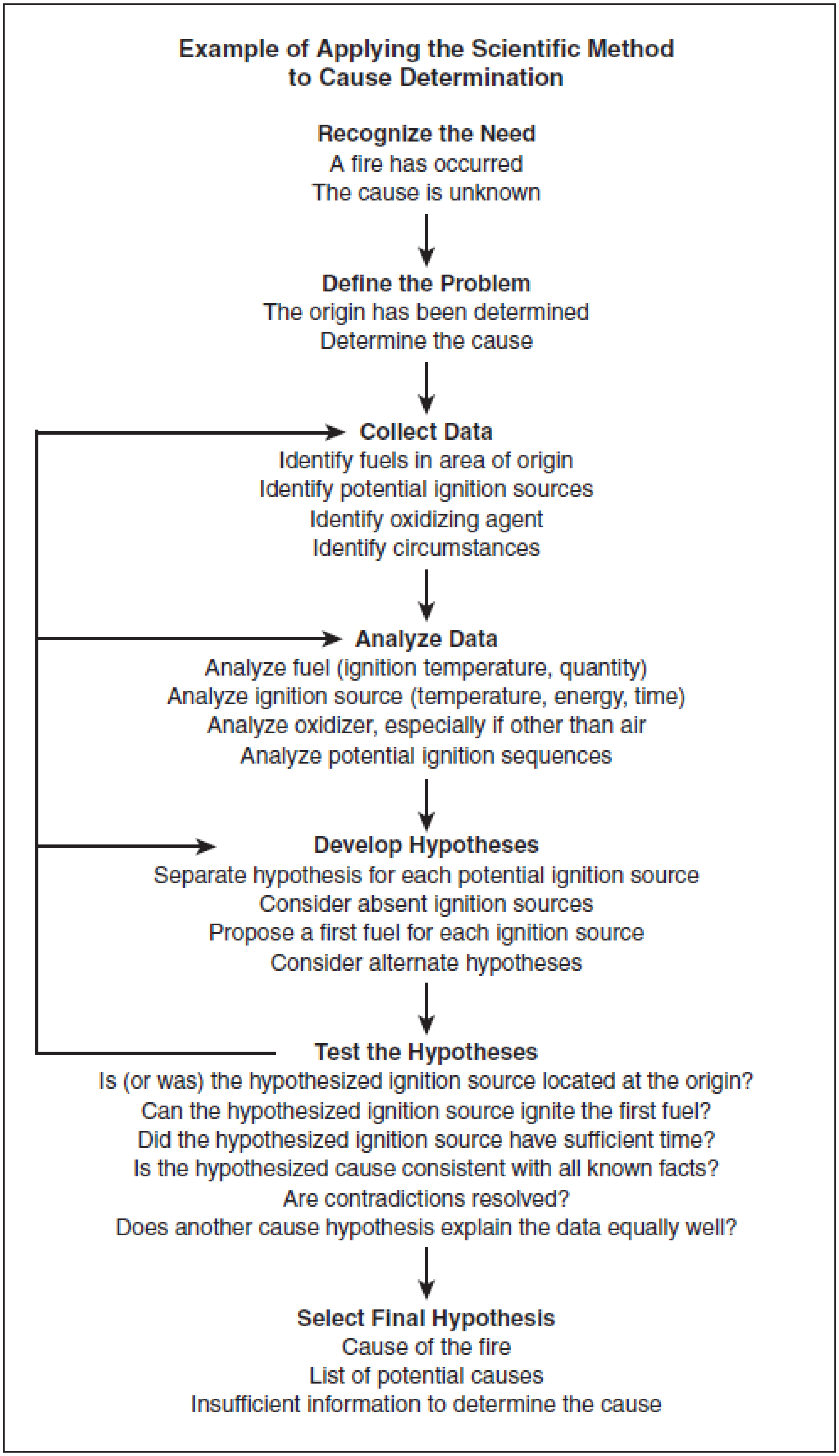


Figure 19.2 An Example of Applying the Scientific Method to Fire Cause Determination.

10.1.1. Consideration of Data

In some instances, a single item, such as an irrefutable article of physical evidence or a credible eyewitness to the ignition, or a video recording, may be the basis for a determination of cause. In most cases, however, no single item is sufficient in itself to allow determination of the fire cause. The investigator should use all available resources to develop fire cause hypotheses and to determine which hypotheses fit all of the credible data available. When an apparently possible hypothesis fails to fit some item of data, the investigator should try to reconcile the two and determine whether the hypothesis or the data is erroneous.

10.1.2. Sequence of Activities

The various activities required to determine the fire cause using the scientific method (data collection, analysis, hypothesis development, and hypothesis testing) occur continuously. Likewise, recording the scene, note taking, photography, evidence identification, witness interviews, origin investigation, failure analysis, and other data collection activities may be performed simultaneously with these efforts. Investigators should refer to the other sections of this guide that deal with these specific activities. Similarly, investigators need to remain aware of potential spoliation and scene contamination issues and should refer to Chapters **12** and **17**.

10.1.3. Point and Area of Origin

In some cases, it will be impossible to determine the point of origin of a fire within the area of origin. Where a single point cannot be identified, it can still be valuable for many purposes to identify the area(s) of origin. In such instances, the investigator should be able to provide reliable explanations for the area of origin with the supporting evidence for each option. In some situations, the extent of the damage may reduce the ability to specifically identify the point of origin, without removing the ability to put forward credible origin and cause hypotheses.

10.2. Data Collection for Fire Cause Determination

Data collection processes for fire cause determination include identification of fuel packages, ignition sources, oxidizers, and circumstances associated with how the fuel and ignition source came together. Data should be collected to identify all potential fuels, ignition sources, and oxidants within the area or areas of origin. Data may also need to be collected from outside the area of origin. Examples of this would be unburned fuel samples or exemplar ignition sources located in other areas. Data on the circumstances bringing the fuel, ignition sources, and oxidizer together may come from many different sources. If available, a review of pre-fire documentation of possible areas of origin can be of value.

10.2.1. Identify Fuels in the Area of Origin

The investigator should identify the fuels present in the area of origin at the time of ignition. One of these fuels will be the first fuel ignited. The type, quantity, and specific location of structural and content fuels should be identified.

Identifying the first fuel ignited is necessary for evaluating the competency of potential ignition sources and understanding the events that caused the fire. Sometimes a portion of the first ignited fuel will survive the fire, but often it does not. The first fuel ignited must be capable of being ignited within the limitations of the ignition source. The components in most buildings are not susceptible to ignition by heat sources having low energy, low temperature, or short duration. For example, flooring, structural lumber, wood cabinets, and carpeting do not ignite unless they are exposed to a substantial heat source. The investigator should identify easily ignited items that, once ignited, could provide the heat source to damage or involve these harder-to-ignite items.

The first fuel ignited could be part of a device that malfunctions or fails. Examples include insulation on a wire that is heated to ignition by excessive current, or the plastic housing on an overheating coffee maker.

The first fuel ignited might be an object that is located too close to a heat-producing device. Examples are clothing against an incandescent lamp or a radiant heater, wood framing too close to a wood stove or fireplace, or combustibles too close to an engine exhaust manifold or catalytic converter.

Certain fuels produce residues not typically found after a fire. These residues differ from construction and contents materials that are normally present in the area of origin. Examples include residues of ignitible liquids or pyrotechnic materials, such as flares.

Gases, vapors, and combustible dusts can be the first fuel ignited and can cause confusion about the location of the point of origin, because the point of ignition can be some distance away from where sustained fire starts in the structure or furnishings. Also, flash fire may occur with sustained burning of light density materials, such as curtains, that are located away from the initial vapor-fuel source.

Information should be sought from persons having knowledge (such as occupants) about recent activities in the area of origin and what fuel items should or should not have been present. Information should also be obtained about the construction of the structure in the origin area. Construction details could include information about the floor, ceiling and wall coverings, type of doors, type of windows, or other information necessary for the analysis. The age of construction materials and attachment methodologies may be relevant. This information could reveal the first fuel ignited for the fire. This information would also be helpful to an investigator to prevent overlooking secondary and subsequent fuels that were present in the origin area that would contribute to fire growth. The investigator should refer to Chapters **5**, **6**, **7**, and **14** when analyzing an origin area for the first fuel ignited.

10.2.2. Identify Source and Form of the Heat of Ignition

The investigator should identify and document all heat-producing items in the area of origin. Heat-producing items include devices, appliances, equipment, and self-heating and reactive materials. The investigator should also identify devices or equipment that are not normally heat producing but may produce enough heat for ignition through misuse or malfunction.

Potential sources of ignition for gases, vapors, or dusts include open flames, arcs from motors and switches, electric igniters, standing pilots or flames in gas appliances, hot surfaces, and static electricity.

10.2.3. Identify Items and Activities in Area of Origin

Information should be obtained from owners and occupants about recent activities in the area of origin and what appliances, equipment, or heat-producing devices were present. This information is especially important when potential ignition sources are not identifiable post-fire. The information would also be helpful in alerting an investigator to small or easily overlooked items when examining the area of origin. When electrical energy sources are considered as potential ignition sources, the investigator should refer to Chapters **9** and **25**. Information on purchase, such as new or used, how and when they were used, repair history, and problems should also be gathered.

10.2.4. Identify the Oxidant

The most common oxidant (oxidizer or oxidizing agent) within a fire is the oxygen in earth's atmosphere, and no special documentation is required. However, other oxidants, as described in **19.3.4.1** through **19.3.4.3**, should be identified and documented when they are in or near the area of origin.

Sometimes oxygen exists at greater than the normal atmospheric concentration, such as in hyperbaric chambers, in oxygen tents, or around oxygen generation, concentration, and storage equipment.

Some chemicals other than molecular oxygen are classified as oxidants. Certain common chemicals, such as pool sanitizers, may also act as oxidants.

Some chemical mixtures, such as solid rocket fuel, contain an oxidizer as well as a fuel and require no external oxidizing source.

10.2.5. Identify Ignition Sequence Data

The investigator should collect data that can be used to analyze the events that brought the fuel and ignition source together (ignition sequence). This information on the conditions surrounding the coincidence of fuel, ignition source, and oxidizer may be available through observations, witness accounts, or weather data. Time lines can be useful in organizing and analyzing this data. *(See Chapter **21**.)* Additional data collection may be necessary in order to determine the circumstances that brought the fuel, ignition source, and oxidizer together. Data collection may continue even after the fire scene has been processed and could require specialized laboratory equipment. Such additional data may result in modification or rejection of previously developed hypotheses or reconsideration of previous rejected hypotheses.

10.3. Analyze the Data

The scientific method requires that all data collected be analyzed. Analyzing the data requires the examination and interpretation of each component of data collected for its role in the fire cause. This is an essential step that must take place in the formation of any hypotheses. The purpose of the analysis is to attribute specific meaning to the results of the examination and interpretation process, which will ultimately play a role in hypothesis development and testing. The identification, gathering, and cataloging of data does not equate to data analysis. Analysis of the data is based on the knowledge, training, experience, and expertise of the individual doing the analysis. If the investigator lacks the knowledge to properly attribute meaning to a piece of data, then assistance should be sought from someone with the necessary knowledge. Understanding the meaning of the data will enable the investigator to form hypotheses based on the evidence, rather than on speculation or subjective belief.

10.3.1. Fuel Analysis

Fuel analysis is the process of identifying the first (initial) fuel item or package that sustains combustion beyond the ignition source and identifying subsequent target fuels beyond the first fuel ignited.

10.3.1.1. Geometry and Orientation

An understanding of the geometry and orientation of the fuel is important in determining if the fuel was the first material ignited. The physical configuration of the fuel plays a significant role in its ability to be ignited. A nongaseous fuel with a high surface-to-mass ratio is much more readily ignitible than a fuel with a low surface-to-mass ratio. Examples of high surface-to-mass fuels include dusts, fibers, and paper. As the surface-to-mass ratio increases, the heat energy or time required to ignite the fuel decreases.

Gases and vapors are fully dispersed (in effect, an extremely high surface-to-mass ratio) and can be ignited by a low heat energy source instantly.

10.3.1.2. Ignition Temperature

The fuel must be capable of being ignited by the hypothesized ignition source. The ignition temperature of the fuel should be understood. It is important to understand the difference between piloted ignition and autoignition temperatures. The components in most buildings are not susceptible to ignition by heat sources of low energy, low temperature, or short duration. For example, flooring, structural lumber, wood cabinets, and carpeting do not ignite unless they are exposed to a substantial heat source.

10.3.1.3. Quantity of Fuel

The first material ignited may not result in fire growth and spread if a sufficient quantity of the fuel does not exist. For example, if the lighter fluid used to start a charcoal fire is consumed before enough heat is transferred to the briquettes, the fire goes out. The investigator should conduct an analysis of the quantity of fuels (primary, secondary, tertiary, etc.) to determine that it is sufficient to explain the resulting fire.

10.3.2. Ignition Source Analysis

The investigator should evaluate all potential ignition sources in the area of origin to determine if they are competent. A competent ignition source will have sufficient energy and be capable of transferring that energy to the fuel long enough to raise the fuel to ignition.

Heating of the potential fuel will occur by the energy that reaches it. Each fuel reacts differently to the energy that impacts on it based upon its thermal and physical properties. Energy can be reflected, transmitted, or dispersed through the material, with only the absorbed energy causing the fuel temperature to rise.

Flammable gases or liquid vapors, such as those from gasoline, may travel a considerable distance from their original point of release before reaching a competent ignition source. Only under specific conditions will ignition take place, the most important condition being concentration within the flammable limits and an ignition source of sufficient energy located in the flammable mixture.

10.3.3. Oxidant

The oxidant is usually the oxygen in the atmosphere. In some cases, alternate or additional oxidants may have been present, and the investigator should consider this and the role of such conditions in ignition and spread.

If the existence of an oxidant other than atmospheric oxygen is suspected based upon the presence of residue, that residue should be collected and analyzed in a laboratory. Typically, the oxidant does not survive in its original form but may leave characteristic residues.

10.3.4. Ignition Sequence

The ignition sequence of a fire event is defined as the succession of events and conditions that allow the source of ignition, the fuel, and the oxidant to interact in the appropriate quantities and circumstance for combustion to begin. Simply identifying a fuel or an ignition source by itself does not and cannot describe how a fire came to be. Fire results from the interaction of fuel, an oxidant, and an ignition source. Therefore, the investigator should be cautious about deciding on a fire cause just because a readily ignitible fuel, potential ignition source, or any other of an ignition sequence's elements is identified. The sequence of events that allow the source of ignition, the fuel, and the oxidant to interact in the appropriate quantities and circumstances for combustion to begin, is essential in establishing the cause.

Analyzing the ignition sequence requires determining events and conditions that occurred or were logically necessary to have occurred, in order for the fire to have begun. Additionally, in describing an ignition sequence, the order in which those events occurred should be determined.

In each fire investigation, the various contributing factors to ignition should be investigated and included in the ultimate explanation of the ignition sequence. These factors should include the following:

- How and sequentially when the first fuel ignited came to be present in the appropriate shape, phase, configuration, and condition to be capable of being ignited

- How and sequentially when the oxidant came to be present in the right form and quantity to interact with the first fuel ignited and ignition source and allow the combustion reaction

- How and sequentially when the competent ignition source came to be present and interact with the fuel

- How and sequentially when the competent ignition source transferred its heat energy to the fuel, causing ignition

- How safety devices and features designed to prevent fire from occurring operated or failed to operate *(see Chapter **25**)*

- How and sequentially when any acts, omissions, outside agencies, or conditions brought the fuel, oxidant, and competent ignition source together at the time and place for ignition to occur

- How the first fuel subsequently ignited any secondary, tertiary, and successive fuels that resulted in any fire spread. If the hypothesized ignition location is not within the main area of fire destruction, then, for the hypothesis to be valid, the investigator should be able to demonstrate that there was a viable fire spread mechanism that facilitated a path of fire propagation along which fire would have been able to propagate

There are times when there is no physical evidence of the ignition source found at the origin, but where an ignition sequence can logically be inferred using other data. Any determination of fire cause should be based on evidence rather than on the absence of evidence; however, there are limited circumstances when the ignition source cannot be identified, but the ignition sequence can logically be inferred. This inference may be arrived at through the testing of alternate hypotheses involving potential ignition sequences, provided that the conclusion regarding the remaining ignition sequence is consistent with all known facts *(see Chapter **4**)*. The following are examples of situations that lend themselves to formulating an ignition scenario when the ignition source is not found during the examination of the fire scene. The list is not exclusive and the fire investigator is cautioned not to hypothesize an ignition sequence without data that logically supports the hypothesis.

- Diffuse fuel explosions and flash fires.

- When an ignitible liquid residue (confirmed by laboratory analysis) is found at one or more locations within the fire scene and its presence at that location(s) does not have an innocent explanation *(see Chapter **23***

- When there are multiple fires *(see Chapter **23**)*

- When trailers are observed *(see Chapter **23**)*

- The fire was observed or recorded at or near the time of inception or before it spread to a secondary fuel

10.4. Developing Cause Hypotheses

The investigator should use the scientific method *(see Chapter **4**)* as the method for data gathering, hypothesis development, and hypothesis testing regarding the consideration of potential ignition sequences. This process of consideration actually involves the development and testing of alternate hypotheses. In this case, a separate hypothesis is developed considering each individual competent ignition source at the origin as a potential ignition source. Systematic evaluation (hypothesis testing) is then conducted with the elimination of those hypotheses that are not supportable (or refuted) by the facts discovered through further examination. The investigator is cautioned not to eliminate a potential ignition source merely because there is no obvious evidence for it.

For example, the investigator should not eliminate the electric heater because there is no arcing in the wires or because the contacts are not stuck. There may be other methods by which the heater could have been the ignition source other than a system failure, such as combustible materials being stored too close to it. Potential ignition sources should be eliminated from consideration only if there is reliable evidence that they could not be the ignition source for the fire. For example, an electric heater can easily be eliminated from consideration if it was not energized.

Devices present at the point/area of origin that are either heat-producing or are capable of heat production when they sustain a fault or failure (e.g., electrical devices of various kinds) should always be placed on the list of hypotheses, even if, for some reason, they are easy to eliminate.

The investigator should consider potential ignition sources that do not correspond to a physical device that can be recovered. Such potential ignition sources include open flames where the device does not remain (e.g., a cigarette lighter was used, but not left at the scene) and static electricity discharges (including lightning). Given the lack of a physical device, other evidence is needed to establish the presence or absence of an ignition source.

For each potential ignition source in the area of origin, it must be established that there existed a fuel or fuels, in an appropriate form and configuration, for which the potential ignition source could be considered a competent ignition source. A cause hypothesis can be developed even in the absence of being able to state specifically which of these fuels was the first ignited.

There may be multiple competent ignition sources in the area of origin with a known first fuel. A cause hypothesis can be developed in the absence of being able to state specifically which of these competent ignition sources ignited the known first fuel. Where propane leaks into a cellar, the standing pilot on either the water heater or the furnace may have been the ignition source; however, post-fire it may not be possible to definitively determine which of the two ignited the gas.

10.5. Testing the Cause Hypothesis for Validity

Each of the alternate hypotheses that were developed must then be tested using the scientific method. If one remaining hypothesis is tested using the scientific method and is determined to be probable, then the probable fire cause is identified.

10.5.1. Scientific Method

Use of the scientific method dictates that any hypothesis formed from analysis of the data collected in an investigation must stand the test of careful and serious challenge by the investigator testing the hypothesis or by examination by others.

10.5.2. Deductive Reasoning

Testing of the hypothesis is done by the principle of deductive reasoning, in which the investigator compares the hypothesis to all the known facts as well as the body of scientific knowledge associated with the phenomena relevant to the specific incident. Ultimately, the cause determination is arrived at through the testing of cause hypotheses.

10.5.3. Hypotheses Testing Questions

In testing a cause hypothesis, the following questions should be answered:

- Is the hypothesized ignition source a competent ignition source for the first fuel ignited?
- Is the required time for ignition consistent with the time line associated with the cause hypothesis and facts of the incident?
- What were the circumstances that brought the ignition source in contact with the first fuel ignited?
- What, if any, were the failure modes required for ignition to occur?

10.5.4. Means of Hypothesis Testing

When testing a hypothesis, the investigator should attempt to disprove, rather than to confirm, the hypothesis. If the hypothesis cannot be disproved, then it may be accepted as either possible or probable. Hypothesis testing may include any application of fundamental principles of science, physical experiments or testing, cognitive experiments, analytical techniques and tools, and systems analysis.

10.5.4.1. Scientific Literature

The use of the scientific literature is an important means to develop information that can be used in hypothesis testing. A review of the literature may include descriptions of experiments and testing that can also be applied to the investigator's specific case. “Gateways” to the scientific literature can include Internet databases, technical libraries, textbooks, and handbooks. The validity of the information in the literature should be considered by the investigator.

10.5.4.2. Fundamental Principles of Science

A cause hypothesis is disproved if it violates the fundamental laws of physics or thermodynamics. Water does not burn — a hypothesis positing the ignition of water would be wrong.

10.5.4.3. Physical Experiments or Testing

Experiments can be conducted to test the hypothesized cause. Care must be exercised in developing an experimental protocol that will produce reliable and applicable results for the specific fire or explosion incident. For more information, see Section **21.5**.

10.5.4.4. Cognitive Experiments

In a cognitive experiment, one sets up a premise and tests it against the data. An example of a cognitive experiment is, “If it were posited that the door was open during the fire and the hinges were found with mirror image patterns, then the hypothesis would be disproved.” For more information see Chapter **4**.

10.5.4.5. Time Lines

In the context of testing a cause hypothesis, the time frame may be a discriminator for determining if an ignition scenario is consistent with the available data as it related to time frames.

10.5.4.6. Fault Trees

Fault trees can be used to test the possibility of a hypothesized fire cause. Fault trees are developed by breaking down an event into causal component parts. These components are then placed in a logical sequence of events or conditions necessary to produce the event. If the conditions or sequence are not present then the hypothesis is disproved.

10.5.4.7. Additional Techniques

Additional analytical techniques and tools in Chapter **21** can be helpful in hypothesis testing.

10.5.5. Appropriate Use

The process of elimination is an integral part of the scientific method. All potential ignition sources present or believed to be present in the area of origin should be identified, and alternative hypotheses should be considered and challenged against the facts. Elimination of a testable hypothesis by disproving the hypothesis with reliable data is a fundamental part of the scientific method. However, the process of elimination can be used inappropriately. 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*. Determination of the ignition source must be based on data or logical inferences drawn from that data. Negative corpus has been used in classifying fires as incendiary, although the process has also been used to characterize fires as accidental. The negative corpus process is not consistent with the scientific method, is inappropriate, and should not be used because it generates untestable hypotheses and may result in incorrect determinations of the ignition source and first fuel ignited. Any hypotheses formulated for the causal factors (e.g., first fuel, ignition source, and ignition sequence) must be based on the analysis of facts and logical inferences that flow from those facts. Those facts and logical inferences are derived from data, observations, calculations, experiments, and the laws of science. Speculative information cannot be included in the analysis.

10.5.5.1. Cause Undetermined

In circumstances where all hypotheses have been rejected, or if two or more hypotheses cannot be rejected, the only choice for the investigator is to conclude that the fire cause, or specific causal factors, is undetermined. It is improper to base hypotheses on the absence of any supportive evidence. That is, it is improper to opine a specific fire cause, ignition source, or fuel that has no evidence to support it even though all other such hypothesized elements were eliminated.

10.5.5.2. Ignition Source vs Fire Cause

The investigator should remember that the fire cause is defined as "the circumstances, conditions, or agencies that bring together a fuel, ignition source, and oxidizer (such as air or oxygen) resulting in a fire or a combustion explosion" *(see **3.3.71**)*. The identification of an ignition source and a first fuel is not sufficient to determine a cause. Determining a fire cause and ignition sequence requires that any proposed hypothesis include consideration of the relationship between the competency of the ignition source and the first fuel ignited. The investigator should determine if the proposed ignition source is a competent ignition source for the proposed first fuel ignited *(see **19.4.2**)*.

10.6. Selecting the Final Hypothesis

Once the hypotheses regarding the “cause” of the fire have been tested, the investigator should review the entire process to ensure that all credible data are accounted for and all credible alternate cause hypotheses have been considered and eliminated. When using the scientific method, the failure to consider alternate hypotheses is a serious error. A critical question to be answered by fire investigators is, “Are there any other cause hypotheses that are consistent with the data?” The investigator should document the facts that support the cause determination to the exclusion of all other reasonable causes.

10.6.1. Establishing the Cause

Although cause is common terminology, the investigator should describe it in terms of the competent ignition source providing enough heat to ignite the first fuel and the circumstances of how they came together. The fuels involved after the first fuel should be noted; this may be especially true when the first fuel is part of the source, such as an appliance. In such a case the subsequent fuels may be the combustibles that are located near the appliance where the fire originated.

10.6.2. Inconsistent Data

It is unusual for all data items to be totally consistent with the selected hypothesis. Each piece of data should be analyzed for its reliability and value. Not all data in an analysis has the same value. Frequently, some analysis or witness statement will provide data that appears to be inconsistent. Contradictory data should be recognized and resolved. Incomplete data may make this difficult or impossible. If resolution is not possible, then the cause hypothesis should be re-evaluated.

10.6.3. Safety Devices and Features

Safety devices and features are often engineered and built to prevent fires from occurring. The cause determination will need to account for the actions of safety devices.

10.6.4. Undetermined Fire Cause

The final opinion is only as good as the quality of the data used in reaching that opinion. If the level of certainty of the opinion is only “possible” or “suspected,” the fire cause is undetermined. This decision as to the quality of data and level of certainty of the opinion’s rests with the investigator.

10.7. Incident Classification

Classifying a fire incident is different from cause determination or analyzing the fire incident for the purpose of assigning responsibility. Classifying a fire incident requires the application of a common language achieved through a classification system that consists of a series of definitions and labels ascribed to certain phenomena. If an incident requires classification, the investigator should refer to the appropriate classification system.

CHAPTER ELEVEN

11.0. ANALYZING THE INCIDENT FOR CAUSE AND RESPONSIBILITY

The purpose of fire and explosion investigations is often much broader than just determining the cause of a fire or explosion incident. The goal of any particular fire investigation is to come to a correct conclusion about the features of a particular fire or explosion incident that resulted in death, injury, damage, or other unwanted outcome.

The features can be grouped under the following four headings: -

a) *The cause of the fire or explosion.* This feature involves a consideration of the circumstances, conditions, or agencies that bring together a fuel, ignition source, and oxidizer (such as air or oxygen), resulting in a fire or a combustion explosion.

b) *The cause of damage to property resulting from the incident.* This feature involves a consideration of those factors that were responsible for the spread of the fire and for the extent of the loss, including the adequacy of fire protection, the sufficiency of building construction, and the contribution of any products to flame spread and to smoke propagation.

c) *The cause of bodily injury or loss of life.* This feature addresses life safety components such as the adequacy of alarm systems, sufficiency of means of egress or in-place protective confinement, the role of materials that emit toxic by-products that endanger human life, and the reason for fire fighter injuries or fatalities.

d) *The degree to which human fault contributed to any one or more of the causal issues described above.* This feature deals with the human factor in the cause or spread of fire or in bodily injury and loss of life. It encompasses acts and omissions that contribute to a loss (responsibility), such as incendiarism and negligence.

Based on the scope of the assignment, an individual investigator may not have the responsibility or be required to address all of the aspects of this chapter.

The cause of a fire or the causes of damage or casualties may be grouped in broad categories for general discussion, for assignment of legal responsibility or culpability, or for reporting purposes. Local, state, or federal reporting systems or legal systems may have alternative definitions that should be applied as required.

11.1. The Cause of the Fire or Explosion

The determination of the cause of a fire requires the identification of those circumstances and factors that were necessary for the fire to have occurred. Those circumstances and factors include, but are not limited to, the device or equipment involved in the ignition, the presence of a competent ignition source, the type and form of the material first ignited, and the circumstances or human actions that allowed the factors to come together to allow the fire to occur.

11.2. The Cause of Damage to Property Resulting from the Incident

The following are considerations that may be utilized in establishing cause of property damage. These factors are divided into two major categories: fire and smoke spread damage and other types of damage.

11.2.1. Fire/Smoke Spread

Elements of damage caused by fire or its products of combustion can further be affected by the following conditions: -

a) *Compartmentation.* Effectiveness or failure of confining the fire and smoke by methods of construction or specific passive fire protection assemblies.

b) *Change of occupancy/hazard.* Change from the original design and use from a lower hazard to a greater hazard without appropriate changes to fire protection, structural, or means of egress features.

c) *Detection/alarm systems.* Failure to provide timely and effective notice of a fire, resulting from a delay in detection or a delay in notification.

d) *Human behavior.* This includes intentional or unintentional acts or omissions by people.

e) *Fire suppression.* Failure of the building fire suppression systems to properly control or mitigate the fire and fire suppression activities may also be factors in fire development or spread.

f) *Fuel loads.* The type, amount, and configuration of fuels affect fire development and spread.

g) *Housekeeping.* Poor housekeeping can contribute to fire damage by providing a more easily ignited fuel configuration and may allow more rapid fire/smoke spread. Poor housekeeping can also obstruct access of fire fighters during suppression activities.

h) *Ventilation.* Fire department ventilation operations, HVAC, and open windows and doors may affect fire growth. Ventilation can also cause smoke and hot gases to move within or from compartments.

i) *Code violations.* Violations of fire safety codes and standards can increase or cause damage (e.g., leaving fire doors open or penetrations of fire walls).

j) *Structural failure.* Failure of building components or systems (utility, fire protection, compartmentation, etc.) can increase damage by allowing or causing fire and products of combustion to spread, providing additional fuels, or impeding fire suppression.

11.2.2. Other Consequential Damage

Other consequential damage can include loss of utilities, subsequent weather damage, corrosion, contamination, water damage, mold damage, or theft.

11.3. The Cause of Bodily Injury or Loss of Life

11.3.1. Fire/Smoke Spread

The following are considerations that may be utilized in establishing the fire-related cause of deaths or injuries:

a) *Toxicity.* Deaths or injuries resulting from exposure to products of combustion.

b) *Hazardous materials.* Deaths or injuries resulting from exposure to hazardous materials released as a result of the fire or explosion incident not directly related to products of combustion.

c) *Compartmentation.* Casualties resulting from improper design or poor performance of compartmentalization features.

d) *Change of occupancy/hazard.* Change from the original design and use from a lower hazard to a greater hazard without appropriate changes to fire protection, structural, or means of egress features.

e) *Detection/alarm systems.* Failure to provide timely and effective notice of a fire, resulting from a delay in detection or a delay in notification, or ineffective notification.

f) *Human behavior.* Human behavior resulting in casualties may include failure to react, inappropriate reaction to notification, or delay in evacuation.

g) *Fire suppression.* Failure of the building fire suppression systems to properly control or mitigate the fire and fire suppression activities may also be factors in fire injuries or deaths.
h) *Housekeeping.* Poor housekeeping can contribute to fire injuries by providing a more easily ignited fuel configuration and may allow for more rapid fire/smoke spread. Poor housekeeping can also obstruct access of fire fighters during suppression activities or egress of occupants.
i) *Fuel loads.* The type, amount, and configuration of fuels affect fire development and spread.

j) *Ventilation.* Fire department ventilation operations, HVAC, and open windows and doors may affect fire growth. Ventilation can also cause smoke and hazardous gases to move within structures, endangering occupants.
k) *Code violations.* Violations of fire safety codes and standards can increase or cause hazards (e.g., exceeding occupancy limits).
l) *Means of egress/refuge.* The inability of occupants to escape or find refuge as a result of improper design, installation, maintenance, operation, or non–code compliance may increase the potential for injuries or death.
m) *Structural failure.* Failure of building components or systems (utility, fire protection, compartmentation, etc.) can increase danger by allowing or causing fire and products of combustion to spread, providing additional fuels, or impeding fire suppression. Structural failure or collapse itself can cause injuries or death.
n) *Intentional acts.* Many of the preceding conditions can be the result of intentional acts, with or without the intent to cause injury or death.

11.3.2. Emergency Preparedness

Failure to properly prepare, test, and implement an appropriate emergency plan can result in casualties.

11.4. Determining Responsibility

After determining the origin, cause, and development of a fire or explosion incident, the fire investigator may be required to do a failure analysis and to determine responsibility. It is only through the determination of such responsibility for the fire that remedial codes and standards, fire safety, or civil or criminal litigation actions can be undertaken.

11.4.1. Nature of Responsibility

The nature of responsibility in a fire or explosion incident may be in the form of an act or omission. It may be something that was done, accidentally or intentionally, that ultimately brought about the fire or explosion, or it may be some failure to act to correct or prevent a condition that caused the incident, fire/smoke spread, injuries, or damage. Responsibility may be attributed to a fire or explosion event notwithstanding the determination of the fire cause. Responsibility may be attributed to the accountable person or other entity because of negligence, reckless conduct, product liability, arson, violations of codes or standards, or other means.

11.4.2. Definition of Responsibility

Responsibility for a fire or explosion incident is the accountability of a person or other entity for the event or sequence of events that caused the fire or explosion, spread of the fire, bodily injuries, loss of life, or property damage.

11.4.3. Assessing Responsibility

While it is frequently a court's role to affix a final finding of responsibility and to assign liability, remedial measures, compensation, or punishment, it is the role of the person who performs the analysis to identify responsibility so that fire safety, code enforcement, or litigation processes can be undertaken.

11.4.4. Degrees of Responsibility

A series or sequence of events or conditions often causes a fire or explosion and the resulting spread, injuries, and damage. A failure analysis often shows that a change to any one or more of these conditions, acts, or omissions could have prevented or mitigated the incident. In this way, responsibility may fall on more than one person or entity. In such a case, multiple or various degrees of responsibility may be assessed.

CHAPTER TWELVE

12.0. FAILURE ANALYSIS AND ANALYTICAL TOOLS

This chapter identifies methods available to assist the investigator in the analysis of a fire/explosion incident. Additional tools requiring special expertise are also discussed. These methods can be used to analyze fires of any size or complexity. In many cases, the methods are used to organize information collected during the documentation of the incident into a rational and logical format. They can also be used to identify aspects of the investigation needing additional information and where future efforts should be directed.

12.1. Time Lines

A time line is a graphic or narrative representation of events related to the fire incident, arranged in chronological order.

The events included in the time line may occur before, during, or after the fire incident. This investigative tool can show relationships between events, identify gaps or inconsistencies in information and sources, assist in witness interviews, and otherwise assist in the analysis and investigation of the incident. A graphic time line is useful as a demonstrative document. The value of a time line is dependent upon the accuracy of the information used to develop the time line.

Estimates of fire size or fire conditions are frequently valuable in developing time lines. Using the tools of fire dynamics analysis, fire conditions can be related to specific events. If there are sufficient events it may be possible to develop an estimate of the heat release history for at least the early stages of a fire.

For example, the observed height of flames, relative to the height of known objects, can be used to estimate the rate of heat release of the fire. Given the response characteristics of detectors and sprinklers, the size of a fire at the time of operation of such devices can be estimated. If the time of operation is recorded at an alarm panel or remote location such as a central alarm service, the estimated size of the fire in the area of the building where the alarm occurred can become part of the time line. Where the detection or suppression systems have multiple zones, the time of operation in each zone can be used to track the spread of the fire through a building and the events can be added to the time line. If the heat release can be estimated for several points in time, a possible heat release history may be postulated and used as one means to assist in testing various hypotheses for the cause and growth scenarios in a given fire.

Fire dynamics analysis can also be used to provide estimated times for relevant events to occur where limited eyewitness observations or hard times are available. Such events include ignition of additional fuels, detector activation, flashover, window breakage, fire spread to adjacent compartments, and occupant incapacitation and death. These analysis tools have acknowledged limitations, and the associated input data are subject to uncertainties. Therefore, estimates of fire conditions and related events in the time line may require to be described as a time interval (e.g., flashover between 10:46 and 10:48) as opposed to a single and specific time (e.g., 10:46).

In order to construct a time line, it is necessary to relate events or activities to the time of their occurrence. In assigning time to events or activities, it is important to identify the confidence the investigator has in the assigned time. One means of doing this is to identify the quality of the data as hard time (actual) or soft time (estimated or relative).

12.2. Hard Time (Actual)

Hard time identifies a specific point in time that is directly or indirectly linked to a reliable clock or timing device of known accuracy. It is possible to have a time line with no hard times. Hard times can be obtained from sources such as the following:

- Fire department dispatch telephone or radio logs
- Police department dispatch and radio logs
- Emergency Medical Service reports
- Alarm system records (on-site, central station, fire dispatch, etc.)
- Building inspection report(s)
- Health inspection report(s)
- Fire inspection report(s)
- Utility company records (maintenance/emergency/repair records)
- Private videos/photos
- Media coverage (newspaper photographer, radio, television, magazines)
- Timers (clocks, time clocks, security timers, water softeners, lawn sprinkler systems)
- Weather reports (TMA, airports, lightning tracking services)
- Current and/or prior owner/tenant records (re: maintenance)
- Interviews
- Computer-based fire department alarms, communications audio tapes, and transcripts

- Building or systems installation permitsll clocks and timing devices are usually not synchronized. Discrepancies between different clocks should be recorded and adjustments made where necessary.

12.3. Soft Time (Estimated)

Soft time can be either estimated or relative time. *Relative time* is the chronological order of events or activities that can be identified in relation to other events or activities. *Estimated time* is an approximation based on information or calculations that may or may not be relative to other events or activities. Often, relative or estimated times can be determined within a known degree of accuracy. For example, they may be bound by two known events or within a time range. It may be desirable to report them as a time range rather than as discrete time.

Relative time can be very subjective in nature. The concept of elapsed time varies with the individual and the stress caused by the incident. It is important for witnesses to be as specific as possible by having them refer to their actions and observations in relation to each other and to other events. All relative time is based on an estimate. It is also possible to have events for which the estimated time cannot be related to a hard time but that are valuable to the analysis. These are referred to as *estimated times*. Relative or estimated times are generally provided by witnesses.

Potential sources of soft times include those sources for hard times listed in **21.2.2.1**, along with estimation of times for an activity to be performed or an event to occur.

12.4. Benchmark Events

Some events are particularly valuable as a foundation for the time line or may have significant relation to the cause, spread, detection, or extinguishment of a fire. These are referred to as *benchmark events*. An example of a benchmark event could be the dispatch and arrival times of the fire fighters as recorded on the fire department incident report. Other examples may include events such as a roof collapsing, a window breaking out, or an explosion.

12.5. Multiple Time Lines

It is quite possible that two or more time lines will be required to effectively evaluate and document the sequence of events precipitating the fire, the actual fire incident, and post-fire activity. These time lines can be called *macro* and *micro*.

A macro evaluation of events may incorporate activity that occurred months before the fire and that terminated on the demolition of the building. As an example, this activity might include renovations that altered the building's electrical system and that may be attributable as the ignition source.

A micro evaluation of events focuses on some discrete segment of the total time line for which the investigator has a particular interest. For example, it may consist of an evaluation of events during the time period immediately prior to ignition, during initial firefighting, during fire growth, or from ignition to extinguishment.

Parallel time lines can be presented to demonstrate two or more series of events. The purpose of such a presentation may be to show whether or not they are related in some manner.

Various tools are available to assist in the development of time lines. Although a simple time line can be constructed with pencil and paper, there are software packages available as well, from simple word processing or database, to sophisticated scheduling software. See **Figure 21.2.5.4** for an example of a simple chronology time line that does not identify hard, soft, or benchmark times and does not graphically display the temporal relationships between events.

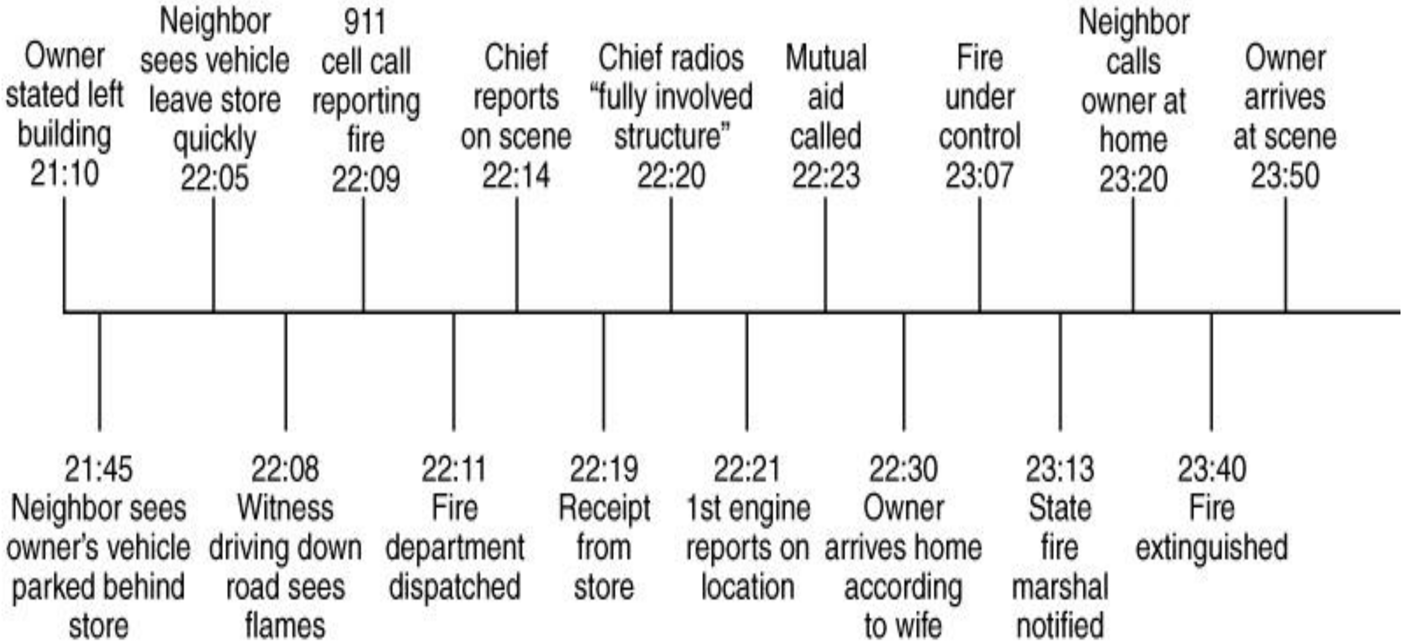


Figure 21.2.5.4 Illustration of a Simple Chronology Time Line.

12.6. Scaled Time Line

A scaled time line displays a list of events that appear on the time line in both chronological and elapsed time relationship to each other. Individual events that are closer together to each other in time are drawn physically closer together on the time line, while events that are further apart in time are further apart on the time line and there is a definite scale or ratio of time to distance along the length of the line. See **Figure 21.2.5.5**. In addition, **Figure 21.2.5.5** identifies hard and soft times by listing hard times above the time line and soft or estimated times below. Hard times in **Figure 21.2.5.5** include when John Doe punched the time clock at work and the reported alarm and arrival times of the fire department, all of which can be correlated to known clocks. Soft times listed in **Figure 21.2.5.5** include estimated times for ignition, smoke alarm activation, and flashover derived from computer modeling, and the estimated time that the eyewitness first became aware of the fire.

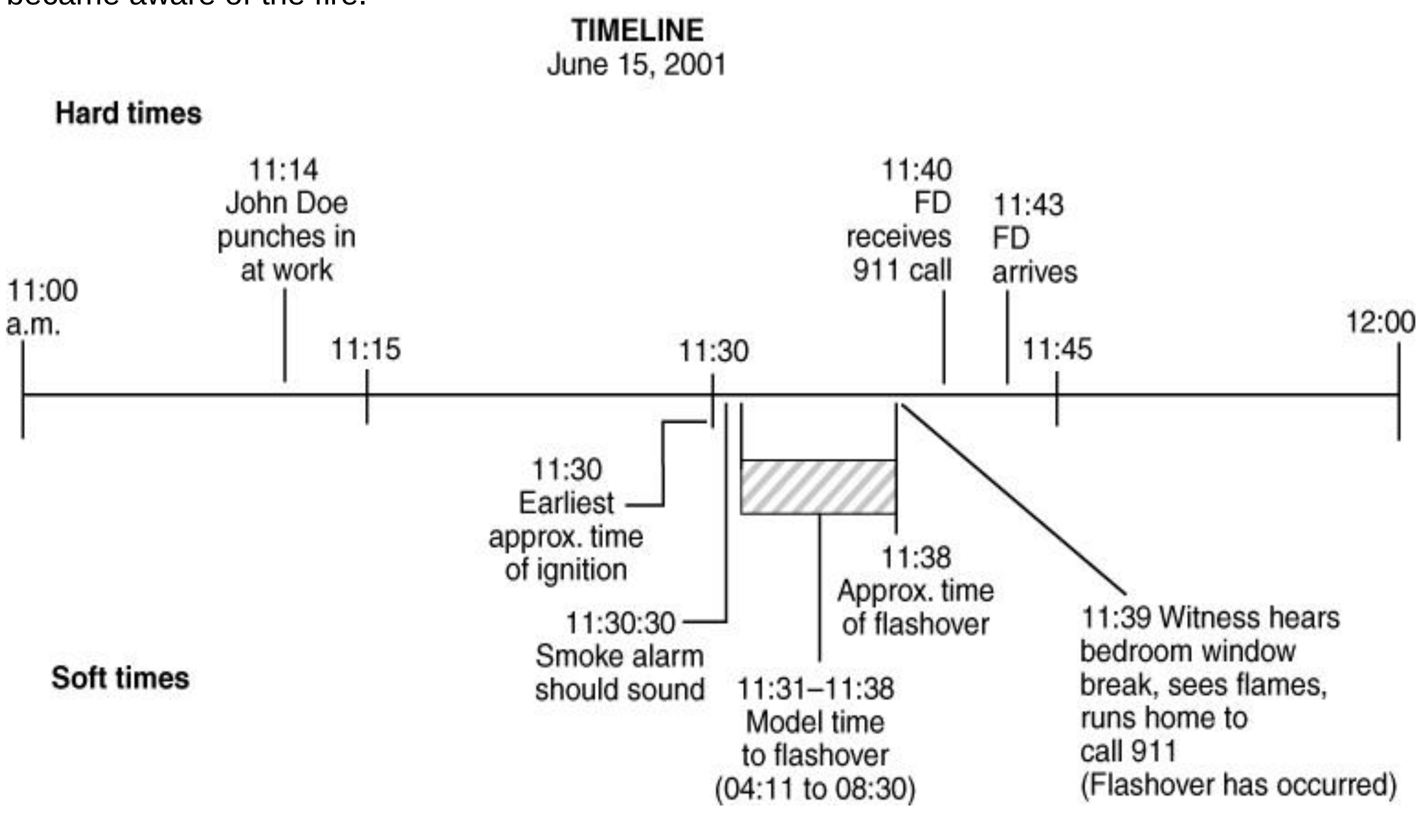


Figure 21.2.5.5 Example of a Scaled Time Line (displaying hard times above the line and soft, or estimated, times below).

12.7. Systems Analysis

Systems analysis techniques are important tools in identifying when and how engineering analysis and modeling may be useful. These techniques, developed for use in system safety analyses, include failure modes and effects analysis, fault tree analysis, HAZOP analysis, and what-if analysis. These tools provide a systematic method for analyzing systems to determine hazards or faults. The tools can utilize either qualitative or quantitative formats. Hazard probabilities or failure rates can be factored in when using quantitative formats.

12.7.1. Fault Trees

A fault tree is a logic diagram that can be used to analyze a fire or explosion. A fault tree is developed using deductive reasoning. The diagram places, in logical sequence and position, the conditions and chains of events that are necessary for a given fire or explosion to occur.

Fault trees can be used to test the possibility of a proposed fire cause or spread scenario and to identify or evaluate possible alternative scenarios. Fault trees are developed by breaking down an undesired event into its causal elements or component parts. The components are then placed in logical sequences of events or conditions necessary to produce the fire or explosion, or into categories of specific aspect of associated damage, death, or injury. If the conditions are not present or if the events did not occur in the necessary sequence, then the proposed scenario is not possible. For example, if the proposed scenario required a live electrical circuit and there was no electrical service, the scenario would be incorrect unless an alternative source for the electricity could be shown. The logic for evaluating the events and conditions that control undesired events is represented by “and” decisions and “or” decisions. In a graphic representation of a fault tree, these decision points are called *gates*. In most cases, fault trees involve combinations of “and” gates and “or” gates, as shown in **Figure 21.3.1.1**.

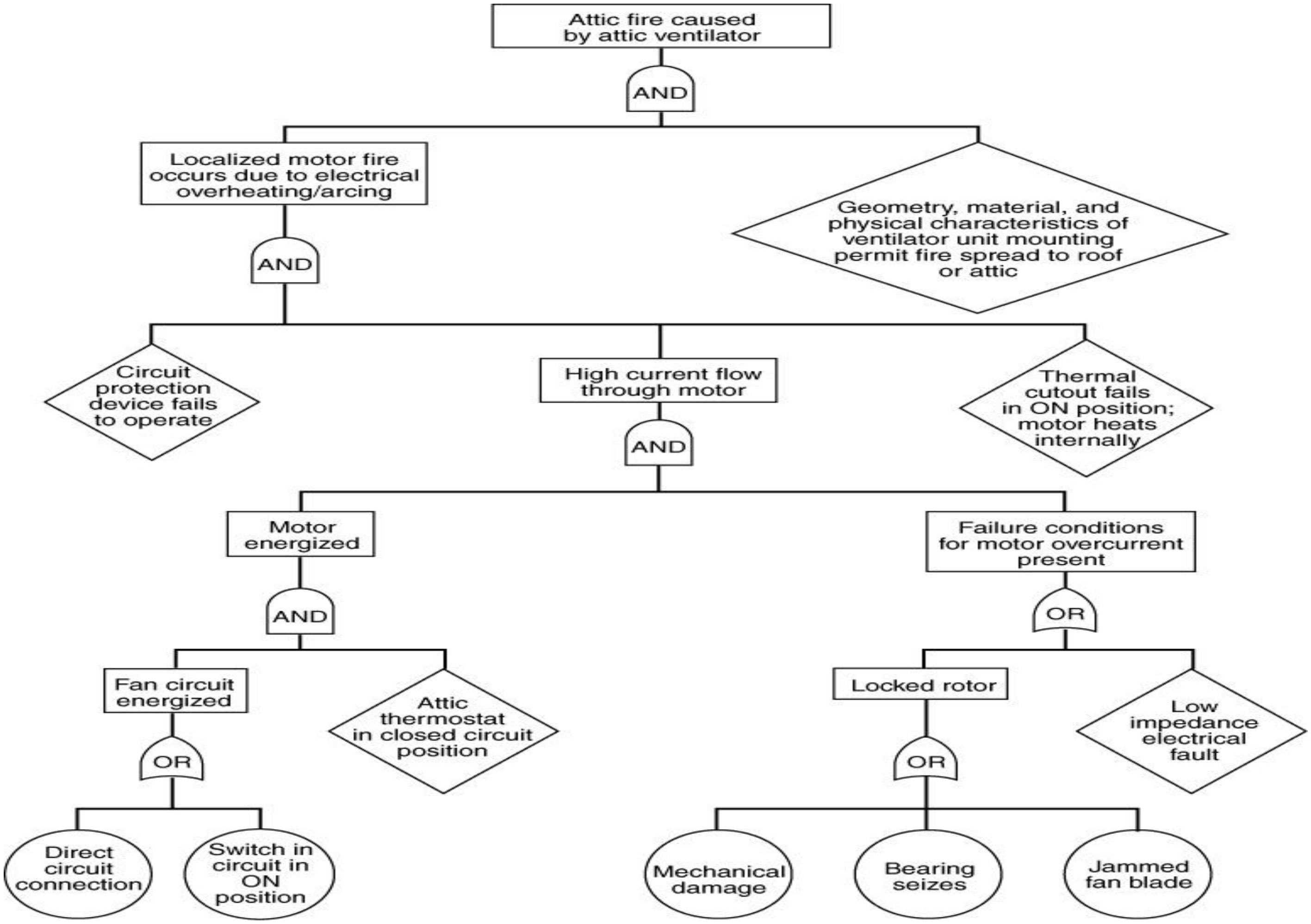


Figure 21.3.1.1 Fault Tree Showing Combination of “And” and “Or” Gates.

For an “and” controlled event to occur, all the elements and conditions must be present. An example using an “and” gate is the set of conditions that must be present for a flashlight to work and produce light. There must be good batteries, the bulb must be good, and the switch must work to produce light. A fault tree for this process is shown in **Figure 21.3.1.2**.

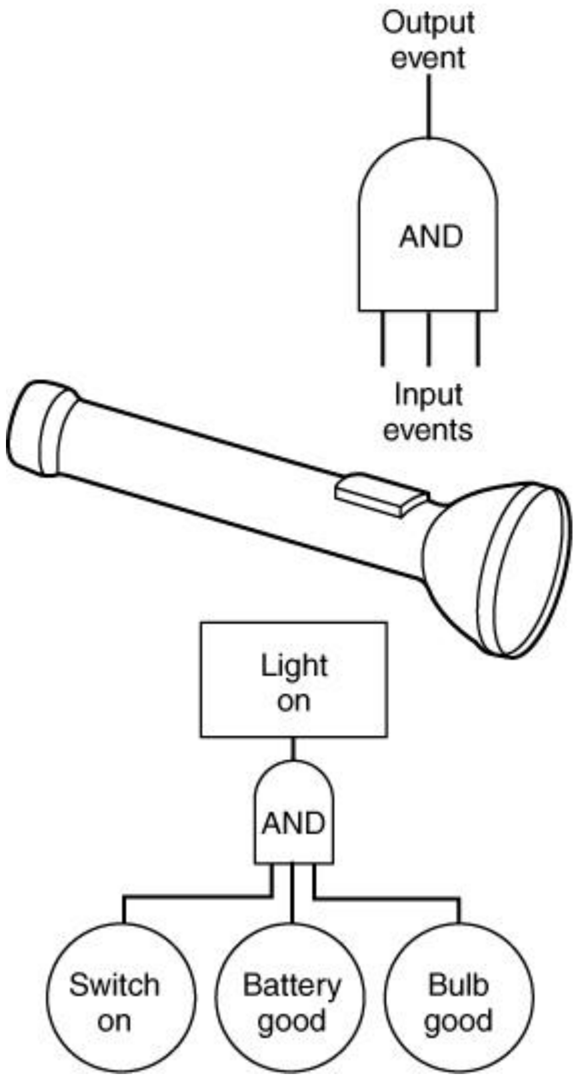


Figure 21.3.1.2 Example of Fault Tree Showing “And” Gate.

For an “or” controlled event, any one of several series of elements and conditions may result in the subject event. An example using an “or” gate would be a flashlight that does not work when the switch is operated. The failure might be due to a switch failure, a blown bulb, or battery problems. **Figure 21.3.1.3** shows the fault tree for this example.

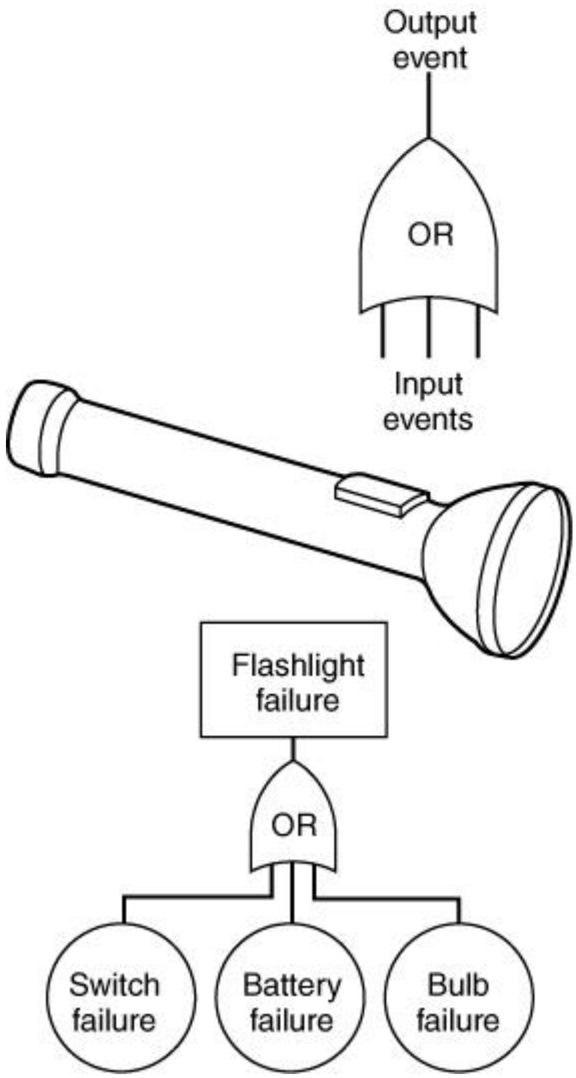


Figure 21.3.1.3 Example of Fault Tree Showing “Or” Gate.

Fault tree analysis may be used to estimate the probability of an undesired event by assigning probabilities to the conditions and events. Assigning reliable probabilities to events or conditions is often difficult and may not be possible.

All system components, their relationships, and the validity of data used need to be identified. In order to construct a fault tree properly, it may be necessary to consult people with special expertise regarding the equipment, materials, or processes involved. The fault tree method of analysis may produce multiple feasible scenarios for a given undesirable event. As a result of insufficient data, it may not be possible to establish which scenario is most likely.

Suggested sources for data to be used in fault tree analysis include the following:

- Operations and maintenance manuals
- Maintenance records
- Parts replacement and repair records
- Design documents
- Services of expert with knowledge of system
- Examination and testing of exemplar equipment or materials
- Component reliability databases
- Building plans and specifications
- Fire department reports
- Incident scene documentation
- Witness statements
- Medical records of victims
- Human behavior information

Fault trees are constructed using a standard format familiar to the technical community. Software is available for assisting the user in developing and analyzing fault trees.

12.7.2. Failure Mode and Effects Analysis

Failure mode and effects analysis (FMEA) is a predictive design technique used to identify basic sources of failure and the effects of a failure within a system, and follows the logical sequence of cause, failure, and effect. In fire/explosion investigations, FMEAs developed by the designers of a component or system can be a valuable reference in helping to determine the cause of an incident. FMEAs are prepared by filling in a table with column headings such as are shown in **Figure 21.3.2**. The column headings and format of the table are flexible, but at least the following three items are common:

- Item (or action) being analyzed
- Basic fault (failure) or error that created the hazard
- Consequence of the failure

Component	Failure mode	Direct effect	Effect on system	Hazard category	Recommended change

Component	Operating mode	Failure mode	Hazardous aspect	Failure frequency	Hazard category	Corrective action

Item	Failure mechanism	Failure rate	Possible hazard	Hazard duration	Source of data	Remarks

Figure 21.3.2 Simplified Examples of Failure Mode and Effects Analysis Forms.

The FMEA concepts and relationships between cause, failure, and effects can be used to help identify potential causes of a fire or explosion and can indicate where further analysis could be beneficial. FMEA is particularly useful in a large or complex incident. It can be effective in identifying factors, both physical and human, that could have contributed to the cause of the fire/explosion. Similarly, it can be helpful in eliminating potential causes of a fire/explosion.

Additional columns are added by the investigator as appropriate, to address the needs of the particular investigation. An assessment of the likelihood of each individual failure mode is frequently included. It is helpful to assess the consequence of a given failure relative to the fire/explosion. FMEA tables can be cataloged by item and can serve as reference material for further investigations. FMEA tables can be developed using computer spreadsheets or specialized software.

When filling out the table, the investigator should consider the range of environmental conditions and the process status (i.e., normal operation, shutdown, and startup) for each item or action. Probabilities or degrees of likelihood can be assigned to each occurrence. When a sequence of failures is required for the incident to occur, the probabilities or degrees of likelihood can be combined to assess the likelihood that any given sequence of events led to the incident.

All known system components and human actions that may have contributed to the incident need to be identified. The accuracy of the determination of the sequence of the events is dependent on the accuracy assigned to each of the individual failure modes.

The data required for an FMEA depend on the extent of the analysis desired. Minimum information typically includes a list of all system components and human actions that may have led to the incident, possible failure modes for each component and action, and the immediate consequences of each failure. It is important to recognize that many system components will have more than one failure mode, so each possible failure mode and its particular consequences should be listed for each component or action.

Data for systems and components can be obtained from many sources, including the following:

- Operations and maintenance manuals
- Maintenance records
- Parts replacement and repair records
- Design documents
- Services of expert with knowledge of system
- Examination and testing of exemplar equipment or materials
- Component reliability databases
- Building plans and specifications
- Fire department reports
- Incident scene documentation
- Witness statements
- Medical records of victims
- Human behavior information

Table 21.3.2.7 shows a hypothetical example of an FMEA applied to a particular fire scenario, in the determination of a cause of that fire.

Table 21.3.2.7 Sample Failure Mode and Effects Analysis for Lunchroom Fire

Component Item	Failure Mode	Cause of Failure	Effects of Failure	Hazard Created	Necessary Conditions
Coffee maker	Heater current flows without shutoff	Switch left on and controls fail	"Boils" out any water in reservoir; thermal runaway of heating element; local temperature increases above 600°C	Ignition of plastic housing	Power on; switch on or fails closed; thermostat fails in ON position; both thermal fuses fail to open
Range (electric)	Autoignition of cooking oil	Unattended cooking Control failure	Oil temperature raised above autoignition temperature	Burning oil fire and large amount of smoke	Unit on; switch on or fails in closed position; no temperature regulation

Note: The data and conclusions presented in this table are hypothetical and used for example purposes only.

12.8. Mathematical Modeling

Mathematical modeling techniques provide the investigator with tools for testing hypotheses regarding the origin and cause of the fire/explosion and the cause of the resulting damage to property or injury to people. Even when the origin and cause are not issues, it is often possible and important to establish the cause of the resulting damage to property or injury to people.

The scope of this discussion emphasizes models and analyses that can be exercised using hand or computer-aided calculations. Usage of these analytical tools depends on the scope of the investigator's assignment, the particular incident, and the practical purpose of the investigation. A special expert may be needed to complete the analysis.

Mathematical models are intended to simulate or predict real-world phenomena using scientific principles and empirical data. There are numerous fields and specialty disciplines that use models.

12.8.1. Limitations of Mathematical Modeling

Mathematical modeling, whether simplified hand calculations or computer fire models, has inherent limitations and assumptions that should be considered. Models generally rely upon empirical data and are validated via comparison with other empirical data. Care must be taken to assure that the model is being used with due regard for limitations, assumptions, and validation. While computational models can be used to test hypotheses, models should not be utilized as the sole basis of a fire origin and cause determination.

In the selection of a mathematical model for use in hypothesis testing, the scope, applicability, basis, and validation and verification of the model should be considered. Models selected should be known to be capable of addressing the technical issues posed in the hypothesis testing. Use of proprietary software may create issues that will need to be addressed, with respect to the ability of other parties to examine the results and use the software.

Inputs to mathematical models are subject to uncertainties that should be considered in the evaluation of model results. The effect of input uncertainties on model results should be assessed through the use of sensitivity analysis. Uncertainties in model inputs may be significantly increased if standardized methods for input determination have not been developed in conjunction with the selected model. Other sources of uncertainty in inputs can result from the use of generic data from the fire science literature or use of exemplar materials for experimental determination of model inputs.

Results of mathematical models are subject to uncertainties resulting from approximations made within the model. The uncertainties introduced by modeling approximations should be considered in hypothesis testing. Information on modeling uncertainties is typically included in validation and verification (V & V) documents. Additional comparisons of model results with relevant existing experimental results may be useful to further establish the V & V basis of the model for use in the investigation.

Input files and output files from computer models should be retained in their original form as part of the investigative record. When input and output files are provided to other parties, the files should be provided electronically in their original form so that they can be used and examined via software intended for that purpose. Files should not be provided as scans or facsimiles, where the ability to use or examine the results via software is limited. As with all discovery issues, parties are free to litigate the reasonableness of the scope of discovery, cost sharing, the burden of production, and the protection of proprietary or trade secrets. Courts can fashion remedies that accommodate and protect the interests of all parties.

12.8.2. Heat Transfer Analysis

Heat transfer models allow quantitative analysis of conduction, convection, and radiation in fire scenarios. These models are then used to test hypotheses regarding fire causation, fire spread, and resultant damage to property and injury to people. Heat transfer models are often incorporated into other models, including structural and fire dynamics analysis. Various general texts on heat transfer analysis are available.

Heat transfer models and analyses can be used to evaluate various hypotheses, including those relating to the following:

- Competency of ignition source *(See Section **19.3**.)*
- Damage or ignition to adjacent building(s)
- Ignition of secondary fuel items
- Thermal transmission through building elements

12.8.3. Flammable Gas Concentrations

Models can be used to calculate gas concentrations as a function of time and elevation in the space and can assist in identifying ignition sources. Flammable gas concentration modeling, combined with an evaluation of explosion or fire damage and the location of possible ignition sources, can be used (a) to establish whether or not a suspected or alleged leak could have been the cause of an explosion or fire, and (b) to determine what source(s) of gas or fuel vapor were consistent with the explosion or fire scenario, damage, and possible ignition sources.

12.8.4. Hydraulic Analysis

Analysis of automatic sprinkler and water supply systems is often required in the evaluation of the cause of loss. The same mathematical models and computer codes used to design these systems can be used in loss analysis. However, the methods of application are different for design than they are for forensic analysis.

A common application of hydraulic analysis is to determine why a sprinkler system did not control a fire. Modeling can also be used to investigate the loss associated with a single sprinkler head opening, to investigate the effect of fouling in the piping, and to determine the effect of valve position on system performance at the time of loss. There are also models and methods available to analyze flow through systems other than water-based systems, such as carbon dioxide, gaseous suppression agents, dry chemicals, and fuels.

12.8.5. Thermodynamic Chemical Equilibrium Analysis

Fires and explosions believed to be caused by reactions of known or suspected chemical mixtures can be investigated by a thermodynamics analysis of the probable chemical mixtures and potential contaminants.

Thermodynamic chemical equilibrium analysis can be used to evaluate various hypotheses, including those relating to the following:

- Reaction(s) that could have caused the fire/explosion
- Improper mixture of chemicals
- Role of contamination
- Role of ambient conditions
- Potential of a chemical or chemical mixture to overheat
- Potential for a chemical or chemical mixture to produce flammable vapors or gases
- Role of human action on process failures

Thermodynamic reaction equilibrium analysis traditionally required tedious hand calculations. Currently available computer programs make this analysis much easier to perform. The computer programs typically require several material properties as inputs, including chemical formula, mass, density, entropy, and heat of formation.

Chemical reactions that are shown not to be favored by thermodynamics can be eliminated from consideration as the cause of a fire. Thermodynamically favored reactions must be further analyzed to determine whether the kinetic rate of the considered reactions is fast enough to have caused ignition, given the particular circumstances of the fire.

12.8.6. Structural Analysis

Structural analysis techniques can be utilized to determine reasons for structural failure or change during a fire or explosion. Numerous references can be found in engineering libraries, addressing matters such as strength of materials, formulas for simple structural elements, and structural analysis of assemblies.

12.8.7. Egress Analysis

The failure of occupants to escape may be one of the critical issues that an investigator needs to address. Egress models can be utilized to analyze movement of occupants under fire conditions. Integrating egress models with a fire dynamics model is often necessary to evaluate the effect of the fire environment on the occupants. See Section **11.3** on human factors.

12.8.8. Fire Dynamics Analysis

Fire dynamics analyses consist of mathematical equations derived from fundamental scientific principles or from empirical data. They range from simple algebraic equations to computer models incorporating many individual fire dynamics equations. Fire dynamics analysis can be used to predict fire phenomena and characteristics of the environment such as the following:

- Time to flashover
- Gas temperatures
- Gas concentrations (oxygen, carbon monoxide, carbon dioxide, and others)
- Smoke concentrations
- Flow rates of smoke, gases, and unburned fuel
- Temperatures of the walls, ceiling, and floor
- Time of activation of smoke detectors, heat detectors, and sprinklers
- Effects of opening or closing doors, breakage of windows, or other physical events

Fire dynamics analyses can be used to evaluate hypotheses regarding fire origin and fire development. The analyses use building data and fire dynamics principles and data to predict the environment created by the fire under a proposed hypothesis. The results can be compared to physical and eyewitness evidence to support or refute the hypothesis.

Building, contents, and fire dynamics data are subject to uncertainties. The effects of these uncertainties should be assessed through a sensitivity analysis and should be incorporated in hypothesis testing. Uncertainties may include the condition of openings (open or closed), the fire load characteristics, HVAC flow rates, and the heat release rate of the fuel packages. See Section **21.6** for recommended data-collection procedures.

Fire dynamics analyses can generally be classified into three categories: specialized fire dynamic analyses, zone models, and field models. They are listed in order of increasing complexity and required computational power.

12.8.8.1. Specialized Fire Dynamics Routines

Specialized fire dynamics routines are simplified procedures designed to solve a single, narrowly focused question. In many cases, these routines can answer questions related to a fire reconstruction without the use of a fire model. Much less data is typically required for these routines than is required to run a fire model.

12.8.8.2. Zone Models

Most of the fire growth models that can be run on personal computers are zone models. Zone models usually divide each room into two spaces or zones, an upper zone that contains the hot gases produced by the fire, and a lower zone that is the source of the air for combustion. Zone sizes change during the course of the fire. The upper zone can expand to occupy virtually all the space in the room.

12.8.8.3. Field, Computational Fluid Dynamics (CFD) Models

CFD models usually require large-capacity computer work stations or mainframe computers. By dividing the space into many small cells (frequently tens of thousands), CFD models can examine gas flows in much greater detail than zone models. Where such detail is needed, it is often necessary to use the sophistication of a field model. In general, however, field models are much more expensive to use, require more time to set up and run, and often require a high level of expertise to make the decisions required in setting up the problem and interpreting the output produced by the model. The use of CFD models in fire investigation and related litigation, however, is increasing. CFD models are particularly well suited to situations where the space or fuel configuration is irregular, where turbulence is a critical element, or where very fine detail is sought.

12.8.9. Guidelines for Selection and Use of a Fire Model

Fire dynamics analyses, particularly those that use fire models, can evaluate hypotheses regarding fire origin and fire development. The methodology for selecting and using a fire model is presented in the SFPE *Engineering Guide: Guidelines for Substantiating a Fire Model for a Given Application* and graphically depicted in **Figure 21.4.9**.

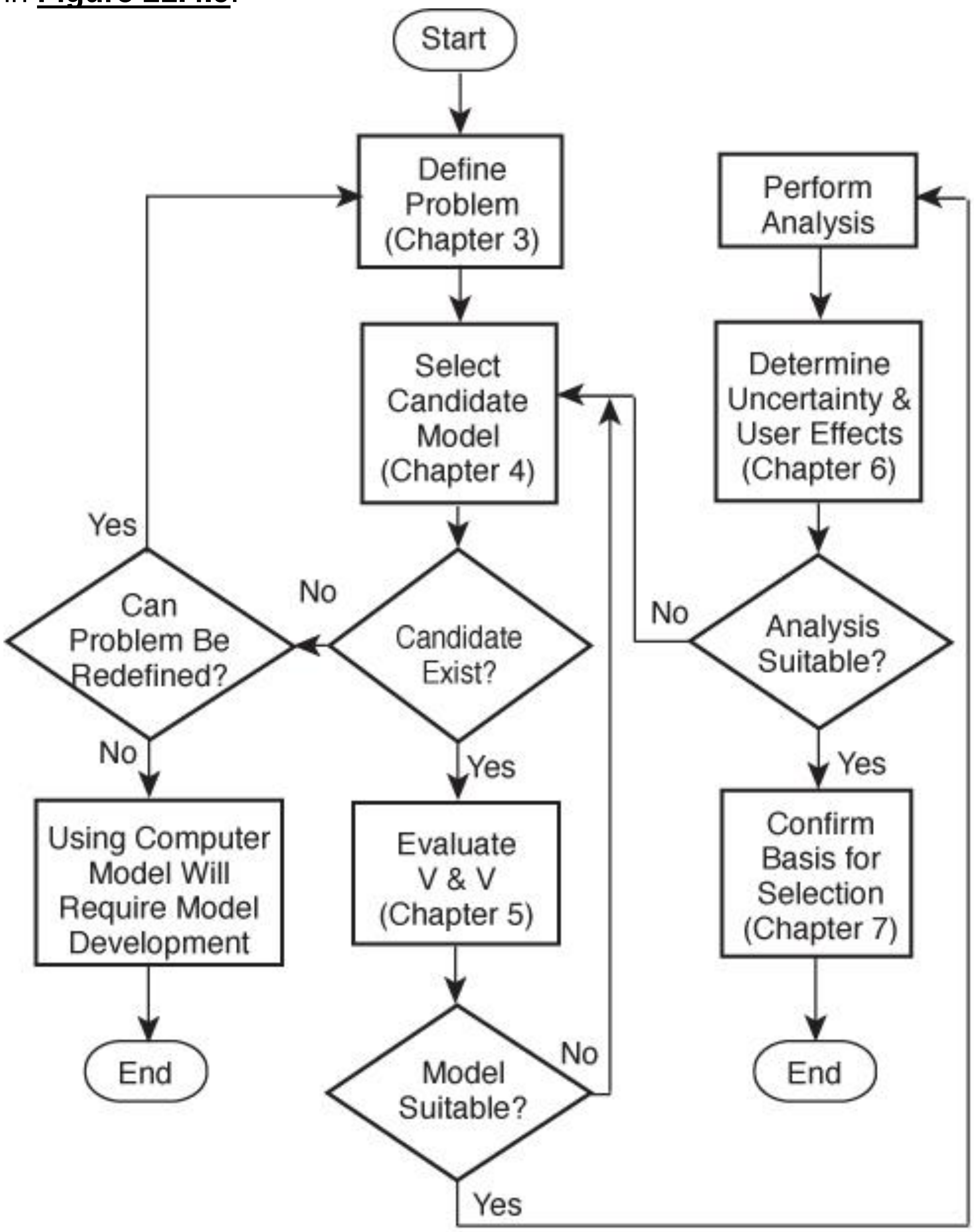


Figure 21.4.9 Fire Model Selection Flowchart.

12.8.9.1. Defining the Problem

The investigator/analyst needs to be able to articulate the question for which modeling is sought. The investigator should state why the problem warrants a numerical study and what fire dynamics assessments of the problem have been previously conducted of this incident. The key fire phenomena and physics should be described (e.g., heat transfer, combustion, and materials response) along with their understanding of how they apply to the problem. The selection process includes determining if a model is applicable to the question and, if applicable, choosing an appropriate model to generate output adequate to answer the question posed.

12.8.9.2. Select a Candidate Model

There is a selection of fire models used for predicting fire phenomena. In addition to the required output, selection factors include computational resources, time limitations, level of accuracy, available input data, and underlying governing equations. The modeler should consider the range of candidate models and may use multiple models for comparison purposes. If no candidate model exists, the problem may require redefinition or a new model may need to be developed. The analyst should evaluate the available information for input to the model, the desired outputs, and the resources available.

12.8.9.3. Model Verification and Validation

The *Guidelines for Substantiating a Fire Model for a Given Application* emphasizes that before selecting a model for a particular problem, the analyst needs to determine if the selected model is capable of generating a useful result. This process, known as verification and validation (V & V), *Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models.* Model developers should have already performed this process, and their V & V data should be available in the documentation.

12.8.9.4. Uncertainty and User Effects

As with any mathematical or computational model, the magnitude or uncertainty of the results relies not only on the model but the choices made for data input and interpretation of the results. This uncertainty is referred to as user effects and must be taken into consideration. User effects can be addressed by conducting evaluations, such as sensitivity analyses or comparison to other model results.

12.8.9.5. Documentation

The documentation of the entire process is important to any case. This documentation should include the following:

- Defining of the problem and key physics and fire phenomena
- Selection of the candidate model or models and their inputs and outputs

- Applicable V & V referenced citations
- Evaluation of user effects
- The data files used with the selected model or model

12.8.10. Fire Testing

12.8.10.1. Role of Fire Testing

Fire testing is a tool that can provide data that complement data collected at the fire scene *(see **4.3.3**)*, or can be used to test hypotheses *(see **4.3.6**)*. Such fire testing can range in scope from bench scale testing to full-scale recreations of the entire event. These tests may relate to the origin and cause of the fire, or to fire spread and development. The components and subsystems to be tested may include building contents, building systems, and architectural and structural elements of the building itself.

Used as a part of data collection, fire testing can provide insights into the characteristics of fuels or items consumed in the fire, into the characteristics of materials or assemblies affected by the fire, or into fire processes that may have played a role in the fire. This information is valuable in the analysis of data and the formation of hypotheses. *(See also Section **17.11**.)*

Used as a part of hypothesis testing, fire testing can assist in evaluating whether a hypothesis is consistent with the case facts and the laws of fire science. In this manner, fire testing is used in much the same way as fire modeling. In addition, fire testing may support modeling by providing input data for models or by providing benchmark data that can be used to assess the accuracy and applicability of a model.

12.8.10.2. Fire Test Methods

To the extent possible, fire test methods, procedures, and instrumentation should follow or be modeled after standard tests or test methods that have been reported in the fire science literature. Tests consistent with standard test methods or the fire science literature will contribute to the scientific credibility of the results. Testing not performed to a recognized standard should be consistent with the relevant facts of the case. Credible testing includes the use of materials and assemblies that are suitable exemplars of actual materials and assemblies, as well as conducting experiments that reflect the relevant conditions of the scene at the time of the fire. Valuable data may be obtained from testing that addresses limited aspects of a fire incident.

12.8.10.3. Limitations of Fire Testing

While fire testing can provide useful information, it is not possible to perfectly recreate all of the conditions of a specific fire that may affect the results of a full-scale test fire. Weather conditions are an example of a parameter that may not be reproduced readily and that may affect the results of a test fire. These conditions should be considered in reaching conclusions that are based on the test results.

12.9. Data Required for Modeling and Testing

Scene data required for modeling and testing, typically obtained by the fire investigator, are used to quantify or characterize the physical scene. Relevant scene data include structural dimensions; type of building materials; size, location, and type of contents; and size, location, and type of sources of ventilation.

12.9.1. Materials and Contents

A meaningful analysis of a fire requires understanding of the heat release rate, fire growth rate, and total heat released. The determination of these parameters requires identification of the types, quantities, location, and configuration of fuel actually involved in the fire. For example, a vertical configuration will burn faster than a horizontal configuration of the same fuel.

The composition, thickness, condition, and layers of the materials comprising the walls, floors, windows, doors, and ceiling should be documented. The ceiling, wall, and decorative finishes, as well as the type, configuration, and condition of contents, should be documented.

12.9.2. Ventilation

Understanding ventilation conditions is important to the validity of a fire test or model. The position and condition of doors, windows, skylights, and other sources of ventilation, such as thermostatically controlled exhaust fans, should be determined. Determining when ventilation sources were opened or closed is important. Ventilation effects may include wind, fire department ventilation, and HVAC operation and should be considered.

CHAPTER THIRTEEN

13.0. MARINE FIRE INVESTIGATIONS

This chapter deals with factors related to the investigations of fires involving boats of less than 272.2 metric tons (300 gross tons) that are used for pleasure or commercial purposes. Included in this discussion are motor boats, sailing boats, yachts, and another watercraft. Information relative to the investigation of boat fires includes construction materials, systems, and failure modes identified in NFPA 302. Additional information regarding boat systems and voluntary industry standards is available from *Standards and Technical Information Reports for Small Craft* published by The American Boat and Yacht Council, Inc. (ABYC). For investigation of boat fires outside U.S. boundaries, additional information may be obtained in local and regional standards and codes. The use of this chapter in the investigation of marine fires within vessels exceeding this length may still be of value. *[See* ***Figure 29.1(a)*** *and* ***Figure 29.1(b)*** *for common terminology.]*

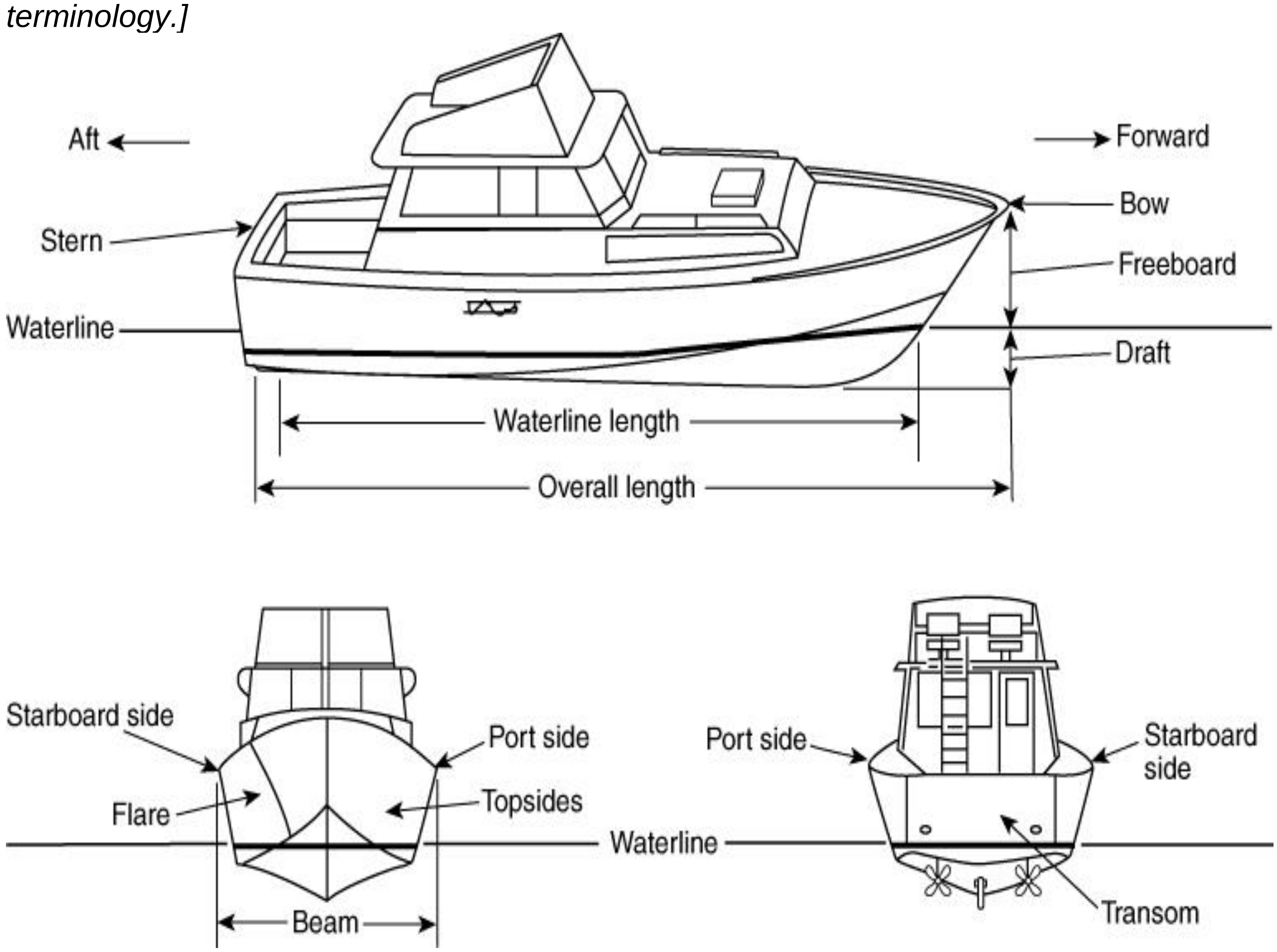


Figure 29.1(a) Powerboat Terminology.

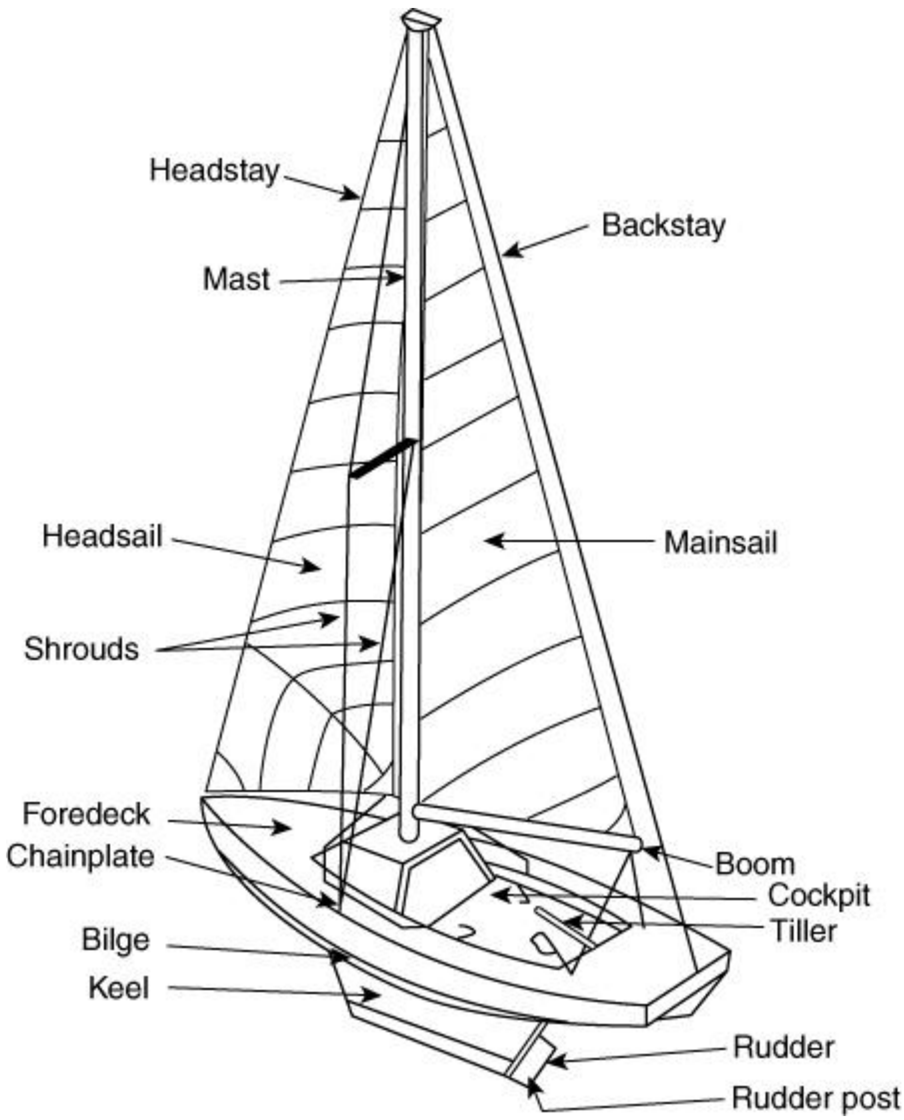


Figure 29.1(b) Sailboat Terminology.

13.0.1. Powerboat and Sailboat Terminology.

The following are terms that apply to **Figure 29.1(a)** and **Figure 29.1(b)**:

- *Accommodation space.* Space designed for living purposes.
- *Adrift. Loose, not on moorings or towline.*
- *Afloat. (1) In a floating position or condition; (2) On a boat or ship away from the shore; at sea. Borne on or as if on the water.*
- *Aft. Toward the rear of the vessel.*
- *Aground. Touching or fast to the bottom.*
- *Beam. The widest point of a vessel*
- *Below. Beneath the deck.*

- *Bilge. The lowest* part of a ship's interior hull.
- *Boat.* Any vessel manufactured or used primarily for noncommercial use; leased, rented, or chartered to another for the latter's noncommercial use; or operated as an un-inspected passenger vessel subject to the requirements of 46 CFR Chapter 1, subchapter C.
- *Bulkhead.* A vertical partition separating compartments.
- *Cabin. A compartment for passengers or crew*
- *Capsize. To turn over.*
- *Chain plate. A metal plate used to fasten a shroud or stay to the hull of a sailboat, which* distributes the force of the shroud.
- *Deck.* A permanent covering over a compartment, hull, or any part thereof.
- in a boat's deck fitted with a watertight cover.
- *Hold.* A compartment below deck in a large vessel, used solely for carrying cargo. *Dock. A protected water area in which vessels are moored. The term is often used to denote a pier or a wharf.*
- *Dorade Vent. Deck box ventilator to keep water out with a baffle while letting air in below decks.*
- *Fender. A cushion, placed between boats, or between a boat and a pier, to prevent damage.*
- *Forward. Toward the bow of the boat.*
- *Freeboard. The vertical distance between the water line and the gunwale.*
- *Galley. The kitchen area of a boat.*
- *Gear. A general term for ropes, blocks, tackle, and other equipment.*
- *Gunwale. The upper edge or surface of a boat's side.*
- *Hatch. An opening*
- *Hull. The structural body of a boat, not including superstructure, mast or rigging.*
- *Inboard. (1) More toward the center of a boat, inside; (2) An engine fitted inside a boat.*
- *Inboard/Out-Drive (I/O). A propulsion system consisting of an engine fitted inside a boat with a stern drive, similar to the lower unit of an outboard motor attached to the transom.*
- *Outboard. (1) Toward or beyond the boat's sides. (2) A detachable engine mounted on a boat's stern.*

- *Overboard. Over the side or out of the boat.*
- *Port. The left side of a boat when looking forward.*
- *Rub Rail. The rubberized, plastic, or metal bumper that extends along both sides of th*e vessel, usually immediately below the gunwales.
- *Shore Power.* Electrical power supplied from shore via a cord set.
- *Shroud. One of the wire cables supporting the mast.*
- *Sole. (1) Cabin or salon floor; (2) Timber extensions on the bottom of the rudder. (3) The molded fiberglass deck of a cockpit.*
- *Starboard. The right side of a boat when looking forward.*
- *Superstructure. The cabins and other structures above deck.*
- *Topside. The sides of a vessel between the waterline and the deck; sometimes referring to onto or above the deck.*
- *Transom. The stern cross-section of a square sterned boat.*
- *Underway. Vessel in motion, i.e., when not moored, at anchor, or aground.*
- *Vessel. Includes every description of watercraft, other than seaplane on the water, used or capable of being used as a means of transportation on the water.*
- *Waterline. A line painted on a hull which shows the point to which a boat sinks when it is* properly trimmed.

13.1. Boat Investigation Safety

As with land-based fire investigations, safety should always be the investigator's first concern. Scene documentation can also be conducted during safety assessment. See Chapter **13** for further information.

Boats on land should be inspected to determine if they are stable before boarding. If not, the boat should be stabilized prior to boarding. Boat shore power connections and the battery supply circuit should be de-energized if they present a safety hazard. The batteries and direct current systems should be inspected with caution. The presence of a dc to ac inverter should be determined and the inverter disabled if necessary. The investigator should employ personal protective equipment (PPE) that is appropriate for the anticipated hazards.

Boats afloat should be approached with extreme caution, as the boat may have water within the hull. Any volume of water within the hull may create an unstable condition within the boat that could cause it to capsize or sink. The water should be removed from the boat (this is called dewatering). Then the boat can be removed from the water and stabilized on land, if necessary, prior to continuing the investigation. The investigator should consider wearing a personal floatation device while working on or near the water.

Underwater inspections of submerged boats present a potential entrapment hazard for a diver.

13.2. Specific Safety Concerns

13.9.1. Confined Spaces

By their nature, fire investigations on boats may involve working in confined spaces. The investigator should be aware of confined space entry concerns (e.g., entry/egress and atmospheric issues), and appropriate precautions should be taken. Persons working in and around confined spaces should be properly trained. Prior to entry, the investigator should ensure the space does not contain hazardous levels of explosive or toxic vapors or gases (i.e., carbon monoxide) or is not oxygen deficient. The hazards of the space should be evaluated before entering, and the appropriate level of personal protective equipment should be worn. Lights and other equipment should be intrinsically safe and suitable for such use. Additional guidance for safe confined space entry and work can be found in NFPA 350.

Prior to entering spaces covered by automatic fire extinguishing systems, the investigator should ensure that the system is disabled or inoperative. Should the system operate while the investigator is inside the compartment, the atmosphere may become toxic or oxygen deficient.

13.9.2. Airborne Particulates

In a fiberglass reinforced plastic (FRP) boat fire, the resin used as part of the construction process generally burns away, leaving small, irritating particles of fiberglass. These particles, when combined with burned resin, are highly irritating to the respiratory system and the appropriate level of personal protective equipment, including respiratory protection, should be worn as indicated by the level of hazard.

13.9.3. Energy Sources

There are numerous energy sources onboard a boat; precautions must be taken to ensure they are disabled to prevent personal injury, as well as possible recurrence of a fire.

13.9.4. Batteries

After proper documentation and photography, battery cables, should be disconnected at each battery, as there may be more than one battery and multiple locations. Prior to disconnecting the battery cables, the investigator should ensure the atmosphere is properly ventilated and free of explosive vapors. During disconnection, arcs from battery terminals can cause a fire or explosion.

13.9.5. Inverters

Inverters that convert dc to 120/240-volt ac power are often found on boats and, after proper documentation and photography, should be disabled by disconnecting the dc input power.

13.9.6. Shore Power

After proper documentation, shore power sources (cord sets) should be de-energized and disconnected. This should be done prior to conducting an investigation.

13.9.7. Fuel Leaks

Engine fuels, heating fuels, and cooking fuels, including propane from onboard LP gas systems can leak due to fire and explosion damage or during investigative activity. Such leaks can produce additional fire hazards. Investigators should be alert to the presence of such leaks and be prepared to prevent or mitigate these hazards.

13.9.8. Sewage Holding Tank

Boats that contain sewage holding tanks may accumulate methane gas. Proper venting and explosion prevention techniques must be employed during the fire scene investigation. Sewage holding tanks may be damaged, and if the contents escape, a biological hazard may be encountered. Care should be taken when working in areas containing sewage.

13.9.9. Hydrogen Gas

Hydrogen gas may be present in any battery compartment. Care should be taken to avoid static discharges, short circuiting, and arcing during the removal of battery cables and batteries.

13.9.10. Other Hydrocarbon Contaminants

The various fluids found onboard boats, as well as the residue left from combustion, contain hydrocarbons that are generally environmental contaminants. Additionally, the presence of these contaminants poses a fire hazard and also presents a danger for slips and falls.

13.9.11. Stability

One of the most dangerous situations an investigator may encounter when examining a boat afloat following a fire is lack of stability. Water entering bilges and lower sections of the boat from fire-fighting activities can cause instability. The investigator should ensure the boat is stable and safe to work in prior to entry for investigation purposes. The boat should be de-watered prior to entry for the investigation. If the boat lists to one side, or turns over, the investigator may become trapped.

13.9.12. Damage to the Structure of the Boat

The boat may have sustained sufficient damage due to the fire, causing it to become unsafe. The structural integrity may be compromised and the weight of the investigator may cause collapse of decking, further resulting in instability. Fires involving the interior can cause structural damage, weakening of the decking, or weakening of structural supports, similar to damage of land-based structures.

13.9.13. Wharves, Docks, and Jetties

Because wharves, docks, and jetties are close to water, seaweed infestation, slime, and slippery surfaces become a hazard to the investigator. The investigator should take care when entering such areas and accessing boats subject to fire damage. Care should also be taken to ensure the structural stability of wharves, docks, and jetties that are attached or in contact with a vessel that has been subjected to fire. Listing vessels may cause these structures to be weakened and/or collapse if they are in contact with the structure, or still tied to these structures.

13.9.14. Submerged Boat

Boats under the water or submerged should be inspected and photographically documented prior to recovery, if possible. When it becomes necessary to conduct an investigation of a boat that has sunk, or is partially submerged, use qualified personnel to carry out the underwater observation and scene search. Recovery efforts should be managed in order to reduce disruption and alteration of the boat and its appurtenances prior to the commencement of topside or land-based investigation activities. Underwater operations may be monitored from the surface. Only qualified divers should conduct underwater investigations.

13.9.15. Visual Distress Signals and Pyrotechnics

Many boats carry distress-signaling devices. These devices can consist of pyrotechnics that can be harmful to the investigator if accidental activation occurs. The investigator should take care to discover and secure any such devices.

13.9.16. Openings

Boats are fitted with all types of openings, some for access to below-deck spaces, and others for access to storage. Some openings are evident, others are not; some are covered by hatches. After a fire, damage may have occurred to hatches and other types of covers concealing openings in the deck. These deck areas may be covered by water and openings may be concealed, creating a hazard for the unwary investigator.

13.3. System Identification and Function

13.9.1. Fuel Systems: Propulsion and Auxiliary

13.3.1.1. Vacuum/Low Pressure Carbureted

Carbureted inboard and inboard/out-drive (I/O) engine systems onboard boats differ from automotive engines in that the carburetors do not allow for the escape of fuel from the venturi in the event of flooding. This is accomplished, in part, by a change in the gasket set for the carburetor when in marine use. Carburetors in marine use are required to meet 33 CFR 183.526, “Carburetors.” Carburetors are required to be fitted with backfire flame arresters.

13.3.1.2. High-Pressure/Marine Fuel Injection Systems, Including Return Systems

Fuel injection systems on inboard and I/O engines in boats generally include a throttle body, plenum and fuel rail assembly, knock sensor, and engine control module. The design of the system is unique to each marine engine manufacturer. In some instances, the fuel injection system for a particular model engine may have three or more different versions. It is important that the investigator record the engine serial number and contact the manufacturer to establish which system design is applicable. The fuel storage and delivery system onboard boats are low-pressure systems and the tank is vented.

13.3.1.3. Diesel

Diesel engines installed in boats utilize manufacturer-specific fuel injection systems. Some of these engines require a 24-volt starting system, while the boat operates on a 12-volt system. The combustion air requirements and ambient engine room temperature require large exchanges of air in the compartment. The fuel system requirements are similar to gasoline.

13.9.2. Fuel Systems: Cooking and Heating

13.3.2.1. Liquefied Petroleum Gases

Liquefied petroleum gases (LPG) can be used as a cooking or heating fuel. The LPG cylinder must be within an enclosure that is vented from the bottom to the outside of the boat. If LPG-fueled cooking devices are installed then all other devices must be ignition protected. Cooking devices with integral LPG containers of less than 450 g (16 oz) are covered under ABYC A-30, *Cooking Appliances with Integral LPG Cylinders.* LPG can be used as a cooking or heating fuel when the appliance meets the requirements of ABYC A-26, *LPG and CNG Fueled Appliances*.

13.3.2.2. Compressed Natural Gas

Compressed natural gas (CNG) has been used as a cooking fuel onboard some boats since the 1980s; however, its popularity has declined in recent years. The CNG cylinder may be located in accommodation spaces if the cylinder is less than 2.8 m^3 (100 ft^3). CNG can be used as a cooking or heating fuel when the appliance meets the requirement of ABYC A-26, *LPG and CNG Fueled Appliances*.

13.3.2.3. Alcohol

Alcohol may be utilized as a fuel in galley ranges. The fuel tank may be an integral component of the stove or a separate container. The fuel can be pressurized by the use of a hand pump.

13.3.2.4. Solid Fuels

Solid fuels, including wood and charcoal, are used in wood burning appliances as covered in NFPA 302.

13.3.2.5. Diesel

Diesel fuel is sometimes used for cooking and heating appliances when in accordance with NFPA 302, *Galley Stoves*, and *Liquid and Solid Fueled Boat Heating Systems*.

13.9.3. Turbochargers/Super Charger

Diesel and gasoline inboard and I/O powered boats can be fitted with turbochargers/super chargers. *(See **Figure 29.4.3**.)* These units often use engine lubrication oil for lubrication and cooling purposes. The units are fitted with heat blankets, water jackets, or a combination of both as their operating temperatures exceed the ignition temperature of surrounding engine room materials. Turbochargers are powered by hot exhaust gases and send pressurized air into the combustion intake. Super chargers, powered by an engine drive belt, inject compressed air into the combustion intake.

13.9.4. Exhaust System

Dry exhaust systems generally exhaust propulsion or auxiliary combustion gases vertically through a pipe that is covered with a heat-insulating blanket. This is not commonly found in recreational boats.

Wet exhaust systems utilize seawater (fresh or salt) that is injected into the exhaust elbow of the engine and travels with the exhaust until it exits the boat. The muffler (if provided) and the hoses of the wet system are specifically designed for the expected temperature and environmental conditions in accordance with ABYC P-1, *Installation of Exhaust Systems for Propulsion and Auxiliary Engines*, and NFPA 302.

De-watered exhaust systems remove the water from the exhaust stream at the muffler and usually route it to the transom while the exhaust gases are routed through the bottom of the boat, in accordance with ABYC P-1, *Installation of Exhaust Systems for Propulsion and Auxiliary Engines*.

13.9.5. Electrical Systems

Alternating current (ac) on boats is provided by shore power, generators, or inverters. When alternating current is supplied via a “shore power” receptacle it should meet NFPA 303 and Article 555 of *NFPA 70*. Additional information on ac systems can be found in Chapter 8 of NFPA 302.

Direct current (dc) systems onboard boats are typically supplied by batteries and provide electrical power for lighting, communications, and navigational equipment Additional information on dc systems can be found in NFPA 302.

13.9.6. Engine Cooling Systems

Liquid coolant systems on inboard and I/O boats are categorized into two groupings: seawater cooled and closed cooled. Seawater-cooled engines pick up seawater via a water pump and circulate it through the engine and discharge it through the exhaust system. Closed-cooled systems circulate the seawater through a heat exchanger and then into the exhaust system. The heat exchanger coolant is usually a 50/50 mixture of propylene glycol and water. Inboard, I/O, and auxiliary engine applications in boats are not air cooled.

13.9.7. Ventilation

Permanently installed fuel tanks are vented from the top via a hose routed overboard and are equipped with a flame arrester. Additional information can be found in 5.6.10–5.6.12 of NFPA 302 and ABYC H-24.13, *Gasoline Fuel Systems*. These vessels will have closed systems that may feature specialized fuel caps, vents, carbon canisters, relief valves, and diurnal controls.

Accommodation spaces in boats may be fitted with hatches and port lights (portholes), which can provide natural ventilation. Some boats are fitted with dorado vents or other ventilation cowls on the cabin top that provide ventilation at all times. The presence of these devices may result in unusual fire ventilation patterns that should be considered during the investigation.

The bilges in the engine and fuel compartments are required to be ventilated as specified in this chapter. The bilge in the accommodation areas is not required to be ventilated.

13.9.8. Transmissions

Mechanical gear transmissions are generally not found on inboard engines. Outboard and I/O propulsion engines have a mechanical transmission located in the gear case.
Hydraulic-geared transmissions are found on inboard and some I/O engines (performance boats). These units have their own oil and cooler. The lube oil is generally SAE 90 weight.

13.9.9. Accessories

Air-conditioning compressors are integrated in heat exchanger units that utilize seawater as a medium to transfer the heat to and from the coils. These units are generally located within the accommodation space, but may be located in the engine room.

Power steering is accomplished by a pump that is belt driven and located on the propulsion engine.

Refrigeration compressors are often located within the appliance and are usually powered by ac and/or dc current. In the event that an LPG refrigerator is in use in an accommodation space, it is required to meet UL 1500, *Standard for Safety Ignition Protection Test for Marine Products*.

Electrical power generation is to be provided by permanently mounted systems utilizing the propulsion engine fuel type (gasoline or diesel) with its own fuel delivery system that meets all applicable requirements of the fuel type. Units are usually mounted in the engine room. Other sources of electrical power supply that should be considered in the investigation are battery chargers, inverters, portable generators, etc.

13.3.9.1. Hydraulic Systems

Trim tabs are powered via a pump motor that is generally ignition protected and that is located adjacent to a small hydraulic tank mounted near the transom.

Hydraulic thruster systems are available, and are generally used in larger boats.

Hydraulic steering systems use either mechanical or electric pumps and piping, either rigid or flexible, in a closed system to assist in steering the boat. This closed system contains hydraulic fluid along with electrical connections that may pose an ignition source for escaping fluids.

13.4. Exterior.

13.9.1. Hull Construction

The investigator should be familiar with the composition of the boat. General building materials for boats are wood, steel, aluminum, ferrocement, and fiberglass-reinforced plastic (FRP). Wood and FRP construction materials should be considered when identifying fuel loads. Some FRP boats utilize core material such as balsa or high-density foam, which during a fire act as a thermal conduction insulator.

13.9.2. Superstructure Construction Material

Materials used in construction of cabins and other structures above the main deck are generally the same as used for the hull.

13.9.3. Deck

Decks are generally the same as hull construction materials; however, they may be inlayed or overlaid with wood, which adds to the fuel load.

13.9.4. Exterior Accessories

Accessories are items or equipment located on the exterior of a boat, such as communications equipment, antennas, navigational aids, search lights, navigation lights, outriggers, handrails, lines, fenders, personal floatation devices (PFDs), life rafts, seat cushions, masts, booms, sails and sheets. Some or all of these items or equipment may be combustible.

13.5. Interior

13.9.1. Construction Materials

Due to weight concerns, the interior construction of a boat may utilize different materials than those found in a normal dwelling. Interiors are generally found to be constructed from fiber-reinforced plastic (FRP) material and/or conventional building materials, such as solid stock woods and exterior grade plywood and veneers. Noncombustible materials such as steel or aluminum may be used for structural components, such as bulkheads.

13.9.2. Finishes

Interior finishes, including wood paneling and carpeted floor (sole), are generally similar to those found in residences and recreational vehicles. Abnormal fire loading may exist in the form of carpeting and other synthetic materials utilized as vertical and overhead finishes. Organic oils (linseed or tung oil) and varnish, paints, etc., that are used on interior finishes may contribute to ease of ignition and fire spread. Counter surfaces may be synthetic (plastic laminate) or wood veneer.

13.5.2.1. Accommodation Furnishings

Accommodation furnishings are those items within a boat that are located in areas that are designed to be occupied by people. Fabric-covered foams utilized in beds and other types of furniture are commonly found, and are similar to those in residences and some motor vehicles, including recreational vehicles.

13.5.2.2. Interior Accessories

Interior accessories may include candles, oil lamps, and other open flame devices. Small appliances that are normally found in residences, including televisions, radios, stereos, and fans are used in boats. Such interior accessories can be a source of ignition.

13.5.2.3. Engine/Machinery Compartments

Engine and machinery compartments on boats may contain, in addition to propulsion engines, batteries, auxiliary generator sets inverters (for the production of 120/240-volt ac power onboard the boat), storage tanks (fuel, water, sewage, hydraulic fluid), bilge pumps, ac and dc electrical system wiring, and in some cases ac and dc electrical panels. Engine compartments may be equipped with fixed automatic fire-extinguishing system equipment (either engineered or pre-engineered). Prior to entering spaces covered by automatic fire-extinguishing systems, the investigator should ensure that the system is disabled or inoperative. Should the system operate while the investigator is inside the compartment, the atmosphere may become toxic, or render the area uninhabitable due to a lack of oxygen from the discharge of the extinguishing agent.

13.5.2.4. Flammable/Explosive Vapor Detectors

These detectors are usually located in the engine compartment(s) and are designed to detect fugitive ignitible vapors *(see **Figure 29.6.2.4**)*. Detectors may also be found in the lower portion of accommodation spaces. Locating and examining these detectors and their operating circuits may provide data indicating whether the device was functional at the time of the fire.

Figure 29.6.2.4 Interior Vapor Explosion.

13.5.2.5. Storage and Holds

Storage and holds are often found in lazarettes, below deck, or under bunks in accommodation spaces. These are provided for the storage of miscellaneous gear and supplies and may contain many different types of combustible materials that should be taken into consideration when conducting a fire investigation. Improper storage of rags and materials containing remnants of organic oils used in maintaining interior finishes may be susceptible to spontaneous heating.

13.5.2.6. Fuel Tanks

Fuel tanks on boats are generally constructed of steel, aluminum, cross-linked polyethylene, or fiberglass and fiberglass with fire-retardant resin. These tanks are subject to rigid construction and testing standards. The investigator may encounter fittings and hoses made of neoprene, synthetic rubber, multilayer flexible laminates, metal, or nylon, all of which may or may not be approved. They may be a source of leakage due to deterioration caused by vibration, age, heat, mechanical damage, etc., or from corrosion due to water (particularly salt water). The investigator should ensure that the fittings and hoses are suitable for the particular use.

13.6. Propulsion Systems

13.9.1. Electric Systems

Although generally not used for the main source of propulsion, many boats are equipped with electric trolling motors powered by batteries. These systems include the motor, one or more batteries, and the electrical conductors used to supply the energy from the batteries to the motor.

13.6.1.1. Bow and Stern Thrusters

Bow and stern thrusters are electrically driven motorized propellers located in horizontal tunnels forward and aft in the boat. These systems are generally 12- or 24-volts dc and utilize a low-amperage circuit to operate a solenoid and a high-amperage circuit to operate the thruster. Circuit protection should be rated accordingly for each circuit. Thermal circuit protection is also commonly installed for the high-amperage circuit.

13.9.2. Fuels for Boats with Motorized Propulsion Systems

13.6.2.1. Fuel Systems

Fuel systems encountered in boats include those for the engine, appliances, and electrical generators.

13.6.2.1.1. Engines

Three general categories of commonly encountered engines and their attendant fuel systems are outboard engines with self-contained or portable fuel tanks; inboard gasoline, and inboard diesel engines.

13.6.2.1.1.1. Outboard Engines (Outboard Motors)

Outboard engines include two-cycle and four-cycle gasoline engines, with either carbureted or fuel-injected systems. Two-cycle engines use fuel and oil mixtures, with the oil either premixed with the gasoline, or supplied in a separate reservoir and automatically mixed with the fuel. The basic principles of four-cycle systems are similar to automobile engines as discussed in Chapter **26**. With outboard engines the fuel is delivered by means of a low-pressure fuel delivery system that includes a pump. The high pressure needed for fuel-injected systems is generated by an engine-mounted fuel pump. *(See*

Figure 29.7.2.1.1.1 Outboard Fuel Filter Fire.

13.6.2.1.1.2. Inboard Gasoline Engines

Inboard gasoline engines are generally four-cycle engines. The fuel system includes built in fuel tanks, fuel lines, filters, and fuel pumps for delivering fuel to the engine. The tanks are required to be vented. When multiple fuel tanks are used, they are often connected with an equalizing line, commonly known as a manifold, to ensure the fuel weight remains evenly distributed. The plate around the fill port is required to be connected to the boat ground, and proper fueling procedure requires that the supply nozzle be in contact with the deck plate before the dock pump is started to prevent static discharge during refueling. The purpose of the fill plate is to prevent incidental fuel spills from draining into the hull. All fittings to the fuel tank are required to be located on the top of the tank, and fuel lines must be routed above tank level to prevent accidental draining of the tank from an open valve or leaking line. Boats built after 1977 are required to be equipped with an anti-siphon valve installed at the tank if the top of the engine is below the level of the top of the fuel tank *(See **Figure 29.7.2.1.1.2**.)*

Figure 29.7.2.1.1.2 Inboard Engine Compartment Fire.

13.6.2.1.1.3. Diesel Engines

The basic operating principles of inboard diesel engines are similar to automotive diesel systems, as discussed in Chapter **26**. The high-pressure fuel injection systems for diesel engines typically include a low-pressure return line to the fuel tank.

13.6.2.1.1.4. Propulsion System Fluids

All propulsion systems contain lubricating fluids that may be sampled and analyzed after a fire to determine prefire conditions.

13.6.2.2. Appliance Fuel Systems

Liquefied petroleum gas (LPG) is the most commonly used fuel for onboard cooking, heating, and refrigeration systems. Considerations are similar to those for automotive systems, as discussed in Chapter **26**. An added consideration for boats is the risk that vapors from leaks may accumulate below deck or in the hull.

13.6.2.3. Electric Generators

Electric generators may be used to supply power for a variety of appliances on a boat. Generators are typically powered using a separate fuel line from the boat's fuel tank.

13.9.3. Other Fuel Systems Used for Propulsion

Most boats are powered by conventional fuels such as diesel and gasoline; however, there are other fuels (e.g., wood, charcoal, coal, and paraffin) that are still being used in steam-powered propulsion systems.

13.7. Ignition Sources

The sources of ignition energy in boat fires are often the same as those associated with structural and vehicle fires (e.g., arcs, overloaded wiring, open flames, and smoking materials). There are some unique sources that should be considered, such as the hot surfaces of turbochargers and manifolds. Because some of these ignition sources may be difficult to identify following a fire.

13.9.1. Open Flames

A common source of an open flame in a carbureted engine is a backfire through an unprotected carburetor. *(See **Figure 29.8.1**.)* In order to prevent these flames from causing a fire, all inboard and I/O boats are required to have an approved backfire flame arrestor attached to the air intake with a flame-tight connection

Figure 29.8.1 Inboard Carburetor Fire.

13.9.2. Electrical Sources

When the engine is not running, the sources of electrical power in a boat are the batteries, inverters, or generators. *(See **Figure 29.8.2**.)* Without a battery disconnect switch, a number of components remain electrically connected to the battery, even though the ignition switch is off and the engine is off. These circuits and components, such as an alternator, ignition switch, or inverter and dc power system, can fail when the engine is off. For instance, the bilge pump is normally installed to remain energized at all times. The investigator should determine if the boat's engine(s) was running at the time of the fire. A boat with its engine running has more potential sources of ignition (e.g., ignition wires, alternators, electrical fuel pumps) than when not running. An example is replacing a marine-approved alternator with an automotive alternator. Protection of electrical circuits in boats is provided by fuses, circuit breakers, or fusible links. As with structures or land-based vehicles, any of these safety devices can be altered, bypassed, or fail. The installation of additional equipment can affect the way a safety device will operate. Unlike the electrical systems of most structures, a boat's electrical systems often use both alternating current (ac) and direct current (dc) systems. Those metallic components located beneath the water line are electrically connected or bonded to the negative side of the dc system to provide lightning protection and to prevent galvanic corrosion.

The negative side of the battery is generally connected to the engine block. The positive side of the battery supplies current to fuses, fuse blocks, or a circuit breaker panel and to all of the direct current electrical equipment. With few exceptions, all circuits are required to consist of two conductors: positive and negative. No metallic portion of the boat may be used for the negative return as per NFPA 302. Any time an energized positive conductor, terminal end, or component comes in contact with a grounded conductor or surface, a completed circuit will occur and may provide a source of ignition.

Boats may have onboard batteries and wiring similar to those utilized in motor vehicles, as well as alternating current (ac) conductors and fixtures similar to a structure. They may also be equipped with a converter that changes the ac (household) current into dc power for battery charging, lighting, and other uses. Boats may be equipped with an onboard generator or a dc to ac inverter to provide ac current when shore power is not available *(see Chapter 10 of NFPA 302)*.

Figure 29.8.2 Power Source Generator.

13.7.2.1. Overloaded Wiring

Faults in wiring can raise the conductor temperature to the point of deteriorating, melting, or igniting the insulation, particularly in bundled cables such as the wiring harnesses or the accessory wiring routed within the boat, through bulkheads, and in cable trays where the heat generated is not readily dissipated. This can occur without activating the overcurrent circuit protection devices. The addition of accessories, such as radios, GPS systems, and radar may contribute to the overloading of the original factory wiring. The prefire history of aftermarket additions and any prior electrical malfunction should be evaluated in the fire analysis.

13.7.2.2. Electrical Short Circuiting and Arcs

Electrical arcing can result when a conductor's insulation becomes worn, brittle, cracked, or otherwise damaged, allowing it to contact a grounded conductor or surface. Insulation failure may occur as a result of chafing, crushing, or cutting of wires. Battery and starter cables are not provided with overcurrent protection and are designed to carry high currents capable of igniting materials such as engine oil accumulations, some plastic materials, and electrical wiring insulation.

13.7.2.3. Electrical Connections

In addition to the electrical failures associated with a structure or vehicle electrical system, corrosion-induced failures may occur from the boat being exposed to water and salt. This corrosion may result in high-resistance heating, providing energy sufficient for ignition of adjacent common combustibles. The electrical connections on a boat should be protected in a similar manner as those comprising the electrical systems for motor vehicles.

13.7.2.4. Lightning

Lightning can cause a boat fire. Due to the size of the lightning charge, an unanticipated current path can occur in any part of the boat from a direct strike. This unanticipated current path can cause the conducting material to ignite, or can ignite nearby combustible material. Lightning strikes, either directly to the boat or indirectly near the boat, can damage electrical system components, creating electrical failures and potentially a fire.

13.7.2.5. Static Electricity and Incentive Arcs

Static electricity and incentive arcs can be an important consideration as a source of ignition in a fire or explosion on a boat. Gasoline vapors are often present during the refueling operation, creating a readily ignitible fuel for this type of ignition source. These vapors may typically collect in below-deck compartments (e.g. engine compartments, cabins, etc.) Fuel system leaks can result in the fuel collecting in the bilge of the boat with the vapors migrating to areas where static electricity may occur from normal activity.

13.9.3. Hot Surfaces

13.7.3.1. Manifolds

Exhaust manifolds and manifold components can generate high temperatures sufficient to ignite diesel spray and vaporized gasoline. Engine oil and transmission fluid coming in contact with a hot manifold can ignite. These fluids may ignite after the engine is shut off due to the loss of cooling water flowing through the engine. When the engine is shut off, the water flow ceases, and manifold temperatures may rise to a level sufficient to ignite atomized fluids or fuel vapors.

13.7.3.2. Exhaust Systems

Commonly, the exhaust systems on boats are different than the exhaust systems found on motor vehicles. One difference may be that the exhaust piping and hoses on a boat are water-cooled. Marine engines can be cooled by water pumped from outside of the boat that passes through the engine and is used to cool the exhaust system. The water is discharged through the exhaust system overboard with the exhaust gasses. The exhaust system on a boat can produce temperatures sufficient to ignite combustibles present in the engine compartment if certain conditions exist, such as a reduced amount of or no cooling water, heavy loading of the engine, rough water conditions, and inadequate spacing from the hot surfaces of the exhaust system to combustibles.

13.7.3.3. Cooking Surfaces

Boat cooking surfaces, if present, usually include a range or oven. The heat is provided by either electricity or by burning propane, compressed natural gas, or alcohol. The hot surface of the electrical heating element or the open flame from the normally operating gas range, oven, or cooking surface can ignite common combustibles found on a boat in the same manner as would occur in a structure. *(See **Figure 29.8.3.3**.)* The same analysis used in a structure should be used in a boat when a cooking surface is considered as a source of ignition.

Figure 29.8.3.3 Cooking Surface Fire.

13.7.3.4. Heating Systems

Some boats utilize fuel gas or electric space heaters. Combustibles in too close a proximity to these heat-producing devices may result in ignition. Some boats utilize reverse cycle heating/cooling units that operate on 120 volts ac and may provide an electrical ignition source.

13.9.4. Mechanical

13.7.4.1. Bearing Failures

The failure of the main bearing in the engine does not usually result in a fire; however, a failure of the bearing in a pulley, motor, alternator, or pump may result in a fire when combustible materials are in contact or in close proximity to the failed bearing. The damage to the bearing after the fire will exhibit physical damage to the race or bearings. These failures of the bearing may result in the release or expelling of hot metal from the bearing.

13.7.4.2. Friction

The drive belts used on some marine engines are the same as those used in motor vehicles. Belts can be ignited if the component pulley fails or locks up and the engine continues to run. The slipping of the belt across the pulley of the failed component can produce temperatures sufficient to ignite the belt, thereby resulting in a fire.

13.9.5. Smoking Materials

In some circumstances, upholstery, fabrics, and materials may be ignited by a cigarette. For example, ignition may occur if a lighted cigarette is insulated (e.g., falling between the back and seat cushions, or into paper, tissues, or other debris). This scenario could occur while the boat is being trailered. Urethane foam seating, once ignited, burns readily and adds substantially to the intensity of a boat fire.

13.8. Documenting Boat Fire Scenes

In general, the requirements for recording and documenting a boat fire incident are similar to those for structures and vehicles. Whenever possible, the boat should be examined in place at the scene. In many cases, however, the investigator may not have the opportunity to view the boat in place. For many reasons, the boat may have been moved before the investigator reaches the scene. Frequently, part of the documentation takes place at a salvage yard, repair facility, marina, boatyard, or warehouse.

13.9.1. On Land

Initially, the investigator should determine if the boat was damaged at its present location or relocated postfire. If it is determined that the fire occurred at another location, that area should be examined if possible. It should be determined if shore power was connected to the boat at the time of the fire. The means of connection to external power should be identified and recorded. Documentation should include other potential ignition sources and fuels in the immediate vicinity of the boat at the time of the fire. It should be determined if the boat was on a trailer or properly shore stored at the time of the fire. An improperly stored boat may be evidence of abandonment, neglect, or theft.

13.9.2. In Water

As on land, the investigator should determine if the boat that is in the water was damaged at its present location or relocated postfire. If it is determined that the fire occurred at another location, that area should be examined if possible. It should be determined if shore power was connected to the boat at the time of the fire. The means of connection to external power should be identified and recorded. Documentation should include other potential ignition sources and fuels in the immediate vicinity of the boat at the time of the fire. It should be determined if the boat was moored, anchored, or underway. It may be necessary, when feasible, to conduct an underwater examination at the fire location for potential evidence.

13.8.2.1. Moored

The location where the boat was moored should be examined for the presence of potential ignition sources and fuels that are not normally considered part of the boat. The examination should include the type or style of structure (slip, dock, seawall, etc.) to which the boat was moored. The investigator should consider and document the construction materials and the type of structure because those materials may affect the fire intensity and spread. Furthermore, the investigator should consider the possibility of the fire having spread from another boat or other outside source (exposure fire).

Figure 29.9.2.1 Generic Boat Fire.

13.8.2.2. Anchored and Underway

The investigator should determine if the fire occurred while the boat was anchored, adrift, or underway, as each may provide different or unique ignition sources. As an example, while at anchor, generators, cooking appliances, etc. may be in operation that would not generally be operating while underway.

13.8.2.3. Underwater

Underwater examination should only be conducted by qualified personnel. When a boat is submerged as the result of a fire, an underwater examination of the boat and the surrounding area should be conducted and documented, if possible. The main purpose of this type of examination is to document the position and condition of the boat prior to attempts to raise the boat.

Figure 29.9.2.3(a) Sunken Boat Recovery.

Figure 29.9.2.3(b) Sunken Boat Recovery.

13.9.3. Boat Identification

Boats, like vehicles, possess unique identifiers, which may vary, depending on the manufacturer and local regulations.

13.8.3.1. Registration Numbers

Boat registration configuration and locations are mandated. Generally, the registration number will appear near the bow of the boat. Ownership information can be obtained through the local regulating authority based on that registration information.

13.8.3.2. Boat Name and Hailing Port

If the boat is properly documented, the hailing port and name will follow documentation requirements. In years past, the hailing port was the location where the boat was normally moored. Currently, the hailing port can be a location chosen by the boat owner. When state-registered, there is no requirement for a boat name or hailing port.

13.8.3.3. Boat History

The general history of the boat, for example, age, alterations, previous owners, repairs, and maintenance records, may provide valuable information to the investigator.

13.8.3.4. Fire Scene History

It is recommended that an attempt be made to develop a scenario of the events leading up to the fire, as well as the progression of the fire itself. The operator of the boat, passengers, bystanders, the Fire and Rescue Force, and police personnel should be interviewed. This information may be used to assist in the investigation.

13.8.3.4.1. Actions Before the Fire

Information regarding the operation of the boat immediately prior to the fire may be obtained from the operator or owner to determine the following:

- When the boat was last operated and for how long
- The total number of hours on the engine
- If the boat systems were operating normally (electrical malfunctions, engine stalling, abnormal handling such as steerage, etc.)
- When the boat was last serviced (e.g., oil change, repairs)
- When the boat was last fueled, including the amount and type of fuel
- When and where the boat was last moored
- When the last time the boat was observed prior to the fire
- What auxiliary equipment was reported present on the boat (e.g., single side band [SSB] radio, CB, GPS, VHF radio, depth finder, fish finders, radar)

- Personal items that were present on the boat (e.g., clothing, tools, recreational items, fishing gear, skis)

13.8.3.4.2. Actions During the Fire

If the boat was occupied or being operated at the time of the fire, the following information may assist in the investigation:

- How long the boat had been in operation and at what speeds
- The route
- Water and weather conditions
- When and where the odor, smoke, or flame was first noticed
- How the boat was reacting at the time the fire was first noticed (e.g., electrical malfunctions, erratic gauge indications, motor racing, etc.)
- Actions taken by the operator when the fire was first noticed (e.g., anchoring, actions if any were taken to extinguish the fire via portable or automatic systems, power disconnection, if and when public officials were notified)
- The length of time the fire burned prior to help being summoned as well as when help arrived
- The estimated time the fire burned until extinguished and by what means
- Other observations

13.8.3.4.3. Actions After the Fire

Information regarding actions or events after the fire may assist the investigator. Those may include the following:

- Information regarding salvage operations if applicable (raising, towing, etc.)
- National Environmental Management Council (NEMC) and similar agency actions, if any
- Actions and location of occupants and fire victims
- Actions taken by other public officials
- Previous investigations

13.9.4. Boat Particulars

Once the boat has been positively identified as being the subject of the investigation, the mechanical functions of that particular boat, its material composition, and its fire reactivity should be reviewed. The investigator may find it helpful to examine an exemplar boat, if one is available, as well as the appropriate sales literature and service manuals. Recall information regarding fire causes in boats of the manufacturer, model, and year may be obtained from the TASAC

13.9. Boat Examination

As with structure fires, the first step is to determine an area of origin. Most boats can be divided into topside/cockpit and three major compartments. The compartments are the engine/fuel compartment (sometimes the fuel is in a separate compartment), the accommodation compartment or cabin, and the bilge. The size, construction, and fuel load of these compartments can vary considerably.

Figure 29.10.1 Marina Fire.

13.9.1. Examination

Examination of the exterior of the boat may reveal significant fire patterns. Caution should be exercised when interpreting patterns around vents for the engine and fuel compartments, as the power blowers may have been operating during the fire, thus affecting the pattern.

Figure 29.10.1.1.1 Burned Boats Inside Marina Building.

An accommodation compartment fire will frequently cause failure at the cabin top from the inside out and may leave the other boat areas largely intact. Analyzing the fire patterns will determine whether the fire spread from inside the compartment. Cabins are relatively airtight when ventilation openings are closed and some fires may self-extinguish. Cabins may have galley equipment that could ignite other combustibles. The spatial arrangements of the cabin, due to its shape, may influence the fire spread characteristics.

Accommodation compartments are those typically used for sleeping, lounging, cooking, storage, head, etc. These multiple configurations result in varied potential ignition sources and fuel loads. Since many of these compartments have limited vertical space, sloping hulls, and offsets, normal structural patterns relied upon by the investigator may not be present.

Engine and fuel compartment fires typically are fuel vapor–related and this may consume the compartment, resulting in fire spread to the cabin and other portions of the boat. Attention should be given to the carburetor or fuel injection systems on the engine, as well as the ignition system components, fuel delivery systems, and fuel tanks. The exhaust system should be inspected for evidence of heat failure (often due to water starvation), which may result in combustion of nearby boat components.

Bilge areas are relatively air stagnant, and water that accumulates within the bilge is frequently pumped overboard via a bilge pump that incorporates a float switch (normally ignition protected). The bilge within each compartment generally is segregated from other compartments, allowing heavier-than-air fuel gases to accumulate within the bilge. Gasoline, diesel, or oil may accumulate in the bilge and will float on top of water in the bilge. Due to the difficulty of cleaning bilges, remnants of these materials may be present at the time of the fire. Once the compartment(s) of origin has been established, a detailed inspection should be made.

13.9.2. Examination of Boat Systems

The individual systems within the boat should be examined to determine their role, if any, in the cause of the fire using the system identifications and functions

The investigator should inspect the fuel tank for edge or bottom failure or corrosion penetrations that may allow the release of fugitive fuel. The conditions of the fuel fill and vent hoses should be inspected for deterioration, chafing, or other damage. The static ground from the fuel tank to the deck fuel fill should be located and its electrical continuity verified.

Fuel tanks, when exposed to heat, generally exhibit a line of demarcation that represents the fuel level at the time the fire was extinguished. Plastic fuel tanks may still be intact, indicating the fuel level at the time the fire was extinguished.

13.9.2.1. Circuit Breakers, Switches, Handles, and Levers

During the inspection of the boat interior, the position of switches and circuit breakers should be noted to determine their position. An attempt should be made to determine if port lights and hatches were open or closed prior to the fire. The position of the circuit breaker handles, battery switches, generator, shore power transfer switch, and so forth, should be noted. The ignition switches should be examined, if possible, for any signs of a key, tampering, or breaking of the lock. Most of these elements are made of materials that may be easily consumed in a fire; however, there may be enough residue left to assist in the investigation.

Figure 29.10.2.2 Switch Positions.

13.10. Boats in Structures

Boats within garages and carports should be examined with consideration of the combustibles within the garage or carport, especially when considering the origin. Heat transfer from a fire originating in the structure may ignite the boat.

During origin and cause determination, boats moored afloat in covered docks should be examined with consideration of the reflected radiant energy from the hot layer developed under the roof and the role of other relevant compartment fire dynamics. These docks are usually floating, and the electrical service to and on the dock should likewise be examined when evaluating the cause.

13.11. Legal Considerations

Unique circumstances encountered in a boat fire may result in the fire investigation being impacted by admiralty law. Admiralty law is a specific area of law that will require specialized legal assistance. Other legal considerations during a boat fire investigation are similar to those involving other investigations and may include the right to investigate, the right to enter, and spoliation and preservation of evidence.

WRITTEN FORMAT FOR PRELIMINARY REPORTS

The following format can be used to construct fire scene investigation reports (when a full narrative is required).

I. Description

- Date (if different than dispatch date).
- Time in 24 hour clock time (time that fire investigation unit arrives on scene).
- Address (corrected when applicable).
- Fire out or still in progress.
- Describe physical characteristics of what burned (structure, vehicle identification. wildland). Give dimensions when possible and detailed descriptions.
- Describe main streets and access to building or property.
- Describe weather/lightning conditions when applicable.
- Identify who requested the response (Incident Command, Police Department, citizen, etc.). Give assignment/unit if known.
- Identify who was dispatched (investigator name and serial number).

II. Observations

- Describe patterns/factors that substantiate area/point of origin.
- Localize area/point of origin by using references within structure, vehicle, or wildland.
- Describe what actually burned (focusing on an area/point of origin)
- Describe unique factors that may exist (trailers, devices, multiple fires, etc.)
- Establish fire cause.
    - Accidental
        - Substantiate accidental fire cause by what existed at area/point of origin.
        - Describe problem(s) that may have contributed to the fire.
        - Establish condition of utilities.
        - Eliminate multiple accidental causes, focusing on a single cause when possible.

- Criminal
    - Establish incendiary cause through physical evidence at scene. (The decision of incendiary cause should be based solely on investigator observations and physical evidence.)
    - Describe in detail, patterns/factors in establishing your incendiary cause.
    - Substantiate multiple fires as being separate and distinct from one another.
    - Establish a negative *corpus delicti* through methodical elimination of all accidental, natural, and mechanical causes.

- Additional Factors to Consider
    - Establish security of premises and type of alarm (contact, motion, supervised, etc.).
    - Alarm company information (phone, address).
    - Status of alarm system at time of fire.
    - Ascertain if safety devices were present (smoke detectors, security bars, sprinklers, etc.)
    - List the existence of evidence observed that would tend to substantiate patterns of unique charring.
    - If multiple fires, describe each fire in detail.
    - Attempt to reference single/multiple fire(s) using points of reference within a structure, vehicle, or wildland area.
    - Establish if structure was locked/unlocked.
    - Determine point of entry (and if forcible entry was used).
    - Describe conditions (construction type, weather, etc.) that may have contributed to the fire.
    - Determine if any additional crimes were involved.

III. Statements

- Obtain witness identification such as driver's license, employee ID card, check-cashing card, etc. (to determine that they are who they say they are).
- Determine where witness(es) can be located for future interview.
- Identify where the interview took place.

- Identify when the interview took place (24-hour clock).
- Identify how the interview took place (in person/by telephone).
- Identify witnesses by last name throughout report.
- Identify witnesses as to their involvement with fire. Use appropriate codes (owner, victim, occupant, witness).
- Take down witnesses' statements exactly as they were given to you.
- Make sure questioning is complete and thorough.
- Suspect Statements:
  - Obtain identification from suspect (if not already known)
  - Identify where the interview/interrogation took place.
  - Identify when the interview/interrogation took place (24-hour clock).
  - Admonish suspects when pertinent, using an approved form (Don't do it by memory!)
  - Use an interpreter when necessary.
  - Write all information completely and thoroughly.
  - Prepare statements carefully and save your notes.
  - Have suspects sign key statements when possible.

IV. Documentation

- Diagrams
  - Fire scene diagrams should be required in the event of a fatality or a serious burn that could result in death.
  - A diagram may be necessary at a complex or complicated fire scene.
  - A diagram may be necessary at a "high visibility" fire scene (celebrities, press release, ec.)
  - A diagram may be included at the discretion of the investigator or when a supervisor suggests that it would benefit the investigation.
- Photographs
  - List number of photographs and attach the photographer's log sheet.
- Evidence
  - List all items of evidence separately on the evidence report. Give location where items were recovered and attach the evidence log.
  - Give physical description of items of evidence.

- Indicate the items to be analyzed, and where they are sent for analysis, in the evidence report. (Lab analysis reports, if completed, can be attached here).
- Make your entries in the Evidence Room Log complete.
- Make entries if any specialized forensic work is to be completed (prints, photos, blood, etc.).

V. Opinion

- If the fire is considered criminal, a more concise opinion (based upon observations and evidence) and that brings all facts together, should be entered.
- If an accidental fire, give the reason(s) why you have reached your conclusion.
- If an undetermined fire, give reason(s) why you have reached your conclusion.
- If a natural fire, give reason(s) for your conclusion.

VI. Attachments

- List any information that may not have been appropriate under other headings.
- List additional work to be completed.
- List status of case and reasons for that determination.
- List agencies/persons notified that are associated with your case.
- Reference reports/records of other agencies and attach copies if appropriate.
- List prior fire incidents involving the same address/people. Attach copies that are pertinent to your case.

ESSENTIALS OF A GOOD REPORT

A. Reports should answer all questions concerning the incident as well as paint a picture.

B. Reports must be proofread.

1. Grammar
2. Punctuation
3. Spelling

C. The overall quality of the report influences the readers' impression of the investigation; therefore, readers must be able to focus on the facts in the case, not errors in the report.

D. Reports should not be "padded" to increase their length.

1. They need to contain the facts pertinent to the case.

2. Reports should not ramble on, but get to the point.

E. Reports must answer the basic questions about the fire and the investigation--who, what, where, when, why, and how.

1. Who?

a. Discovered the fire.

b. Extinguished the fire.

c. Provided scene security.

d. Has pertinent knowledge.

e. Was the victim.

f. Made the report.

g. Has a motive for the crime.

2. What?

a. Happened.

b. Actions were taken.

c. Was the damage.

d. Was the crime.

e. Do witnesses know.

f. Was done with the evidence.

g. Is the chain of custody of the evidence.

h. Agencies are involved.

3. Where?

a. Did the fire start.

b. Did the fire travel.

c. Was the witness.

d. Were the owners/occupants.

e. Was the evidence collected.

f. Is the evidence stored.

g. Was the crime committed.

4. When?

a. Was the fire first discovered.

b. Was it reported.

c. Was the investigation conducted.

d. Were the interviews conducted.

5. Why?

a. Did the witnesses make statements.

b. Were the witnesses reluctant to talk.

c. Was the crime committed.

6. How?

a. Was the fire discovered.

b. Did the fire start.

c. Was the evidence collected.

d. Was the evidence secured.

e. Did the suspect arrive.

f. Did the suspect leave.

WRITING THE REPORT

A. Preparation is the first step in writing any document.

1. All necessary information must be collected and compiled before the report can be written.

2. Material must be arranged in a systematic order.

3. Material not pertinent to the case should be discarded.

4. The use of an outline assists the investigator in ensuring his/her report is in chronological order.

B. The final investigative report will be read by peers, supervisors, the public, and colleagues.

1. Correct grammar, spelling, and punctuation are essential.

a. Misspelling and improper grammar can give the entire investigation a sloppy appearance.

b. Each document needs to be proofread for completeness and accuracy.

2. Use the first person.

a. "I arrived at the scene..."

b. "I observed..."

3. Avoid second or third person.

a. "This investigator..."

b. "This officer observed..."

4. Determine the target audience and write the report for that audience. Remember, the person reading the report may know nothing about fire investigation.

5. Avoid terminology that only fire investigators understand.

a. If you do use terminology that is known only to experts, then be sure to explain the terms, for example:

- "V patterns." Explain that these patterns point toward the area of origin.
- "Liquid accelerant pour patterns." Explain that you found a pattern which is typical of the use of accelerants.

b. Avoid terminology that cannot be explained.

- It "smelled like Benzene." (This is a hard odor to describe.)

6. Use a writing style that is simple and to the point.

7. Keep your paragraphs short. Long paragraphs tend to turn off most readers.

8. Write the way you talk. Your written communication should reflect your oral communication.

9. Reports should contain only material and information pertinent to the investigation.

10. Personal opinions, conclusions, and suspicions should be eliminated.

11. However, the expert opinion of a qualified investigator based on the evidence found should be included in the report.

12. Reports are statements of fact and observations discovered by the investigator, written in an objective, factual manner.

THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF HOME AFFAIRS
FIRE AND RESCUE FORCE

Telegrams: "NATIONAL FIRE"
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Email: **fire.rescue@frf.go.tz**

Office of The Commissioner General
Fire and Rescue Force
P. O. Box 1509
Dodoma

FIRE INVESTIGATION REPORT FORM

FIRE INVESTIGATION **INCIDENT**	STATION		CALL No.		FILE No.
CALL	**DAY OF CALL**	**DATE OF CALL**	**TIME OF CALL**		**TIME OF ARRIVAL**
METHODS OF CALL	☐ **ALARM** ☐ **PHONE** ☐ **RUNNING**		**TIME UNDER CONTROL**		**TIME FIRE SUPPRESSED**
ADDRESS/LOCATION	**PLACE OF INCIDENT**	**OTHER STATION(S) INFORMED /AGENCY PARTICIPATED**			
WEATHER AT **TIME OF FIRE**	**GENERAL CONDITION** **ROAD CONDITION**		**TEMPERATURE**	**WIND DIRECTION**	**WIND SPEED**
PROPERTY DESCRIPTION	☐ **STRUCTURE (04)**	☐ **VEHICLE**	☐ **WILDLAND**	**OTHER (STATE)**	
FIRE DISCOVERY	**DISCOVERED BY**			**TIME DISCOVERED**	

VEHICLE DESCRIPTION					
COLOR (S)	**YEAR**	**MAKE**	**MODEL**	**LICENSE – NO., STATE, EXPIRES**	**VEHICLE ID**

OWNER/OCCUPANT		
OWNER'S NAME	**ADDRESS**	**PHONE NO.**
OCCUPANT'S NAME	**ADDRESS**	**PHONE NO.**
NATURE OF BUSINESS CARRIED ON		

ALARM/PROTECTION SYSTEMS		
ALARMS ☐ **YES** ☐ **NO**	**TYPE ALARM**	
ALARM COMPANY	**CONTACT PERSON**	**PHONE No.**

COMMENTS (WHEN ALARM RECEIVED)	
PROTECTION SYSTEMS ☐ YES ☐ NO ☐ OPERATED ☐ DID NOT OPERATE	STATE TYPE OF SYSTEMS / APPLIANCE OPERATED

CASUALITY DESCRIPTION

NAME	ADDRESS	PHONE NO.

SEX	AGE	DATE OF BIRTH	HEIGHT	WEIGHT	HAIR	OTHER

DECRIBE CLOTHING

TYPE OF INJURY

☐ MINOR ☐ MODERATE ☐ SEVERE ☐ FATAL	DESCRIBE INJURY
WHERE VICTIM FOUND?	

CASUALITY TREATMENT

☐ TREATED AT SCEEN BY?		
SENT TO	BY	HOSPITAL / DISPENSARY NAME

REMARKS

NEXT OF KIN

NAME	RELATIONSHIP	ADDRESS	PHONE

NOTIFIED BY (How, Date, and Time)

WITNESS STATEMENT

NAME	ADDRESS	PHONE No.

SEX	AGE	DATE OF BIRTH	NATIONAL ID No.	OTHER ID No.

RELATIONSHIP TO INCIDENT	

STATEMENT TAKEN BY	LOCATION	DATE	TIME

STATEMENT

EVIDENCE

	DESCRIPTION	WHERE FOUNDED/WHEN	REMOVED TO/BY
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

REMARKS

PHOTOGRAPH

	DESCRIPTION
1	
2	
3	

4	
5	
6	
7	
8	
9	
10	

REMARKS	

OTHER AGENCIES INVOLVED			
FIRE AND RESCUE FORCE	INCIDENT NO.	CONTACT PERSON	PHONE NO.
POLICE FORCE	FILE NO.	CONTACT PERSON	PHONE NO.
OTHER	CASE NO.	CONTACT PERSON	PHONE NO.

ESTIMATED TOTAL LOSS	
TSH.	ESTIMATED BY

REMARKS	

Note: fully completed report is subject to submission of the following requirements

1. **Documents indicating the value of damaged properties**
2. **Picture taken before and after arrival of fire and Rescue Force**
3. **Sketch if any**

Approved by:

Full name: ……………………………………………………… Designation ………………………

Signature & Stamp ……………………………………

Date…………………………………

Commissioner General, Fire and Rescue Force
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