18.3.3.3 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.)*

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18.3.3.4 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.

18.3.3.5 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.

18.3.3.6 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.

18.3.3.7 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.

18.3.3.8 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.

18.3.3.9 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.

18.3.3.10 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.

18.3.3.11 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.

18.3.3.12 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.

18.3.3.13 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.

18.3.3.14 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.

18.4 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.

18.4.1 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.

18.4.1.1 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.

18.4.1.2 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.

18.4.1.3 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.

18.4.1.3.1 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.

18.4.1.3.2 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.

18.4.1.4 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.

18.4.1.5 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.

18.4.1.6* 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.

18.4.2* 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.

18.4.2.1 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.

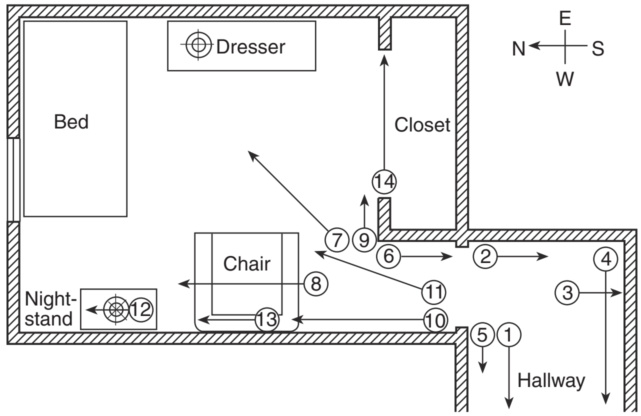


FIGURE 18.4.2(a) Heat and Flame Vector Analysis Diagram Associated Vectors of the Physical Size and Direction of Heat Travel of the Fire Patterns and Demonstrating a Fire Origin in the Area of Vectors 7, 8, and 10.

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.

18.4.2.2 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.

18.4.2.3 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).]*

18.4.3 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

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

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.

18.4.4 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.

18.4.4.1* 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.

18.4.4.2* 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.

18.4.5* Origin Matrix Analysis.

Δ **18.4.5.1*** 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.

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

Δ **18.5 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.

18.5.1 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.

18.5.2 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.

18.6 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.)*

18.6.1 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.

18.6.1.1 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.

18.6.1.2 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.

18.6.1.3 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.

18.6.2 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.

18.6.2.1 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.

18.6.2.2 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.

18.6.2.3 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.

18.7 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.

18.7.1 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.

18.7.2 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 reevaluated.

18.7.3 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.

18.8 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.

18.8.1 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.

18.8.2 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.

18.8.3 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 19 Fire Cause Determination

19.1 Introduction. This chapter recommends a methodology to follow in determining the fire cause. Fire cause 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.

19.1.1 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.

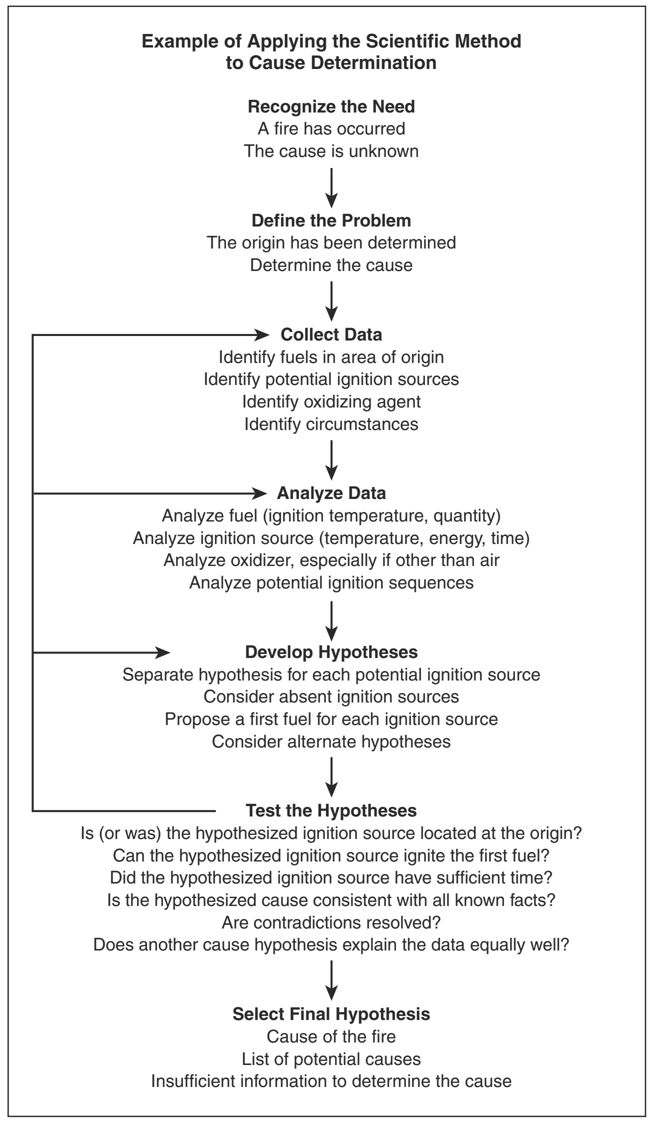
19.1.2 First Fuel Ignited. The first fuel ignited is that which first sustains combustion beyond the ignition source. For example, the wood of the match would not be the first fuel ignited, but paper, ignitible liquid, or draperies would be, if the match were used to ignite them.

19.1.3 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.

Δ **19.1.4 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)*.

Δ **19.1.5 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.

Δ **19.2 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.)*



Δ **FIGURE 19.2 An Example of Applying the Scientific Method to Fire Cause Determination.**

19.2.1 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.

Δ **19.2.2 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.

19.2.3 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.

19.3 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.

19.3.1 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.

Δ **19.3.1.1** 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. *(See 5.6.1.)*

Δ **19.3.1.2** 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.

19.3.1.3 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.

19.3.1.4 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.

19.3.1.5 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.

Δ **19.3.1.6** 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.

Δ **19.3.2 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.

19.3.2.1 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.

Δ **19.3.3 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.

19.3.4* 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.

19.3.4.1 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.

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

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

19.3.5 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.

Δ **19.4 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.

19.4.1 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.

19.4.1.1 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.

19.4.1.2 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.

19.4.1.3 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.

Δ **19.4.2 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.

19.4.2.1 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.

19.4.2.2 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.

19.4.3 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.

Δ **19.4.3.1** 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.

19.4.4 Ignition Sequence.

19.4.4.1 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.

19.4.4.2 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.

Δ **19.4.4.2.1** 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:

(1) 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
(2) 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
(3) How and sequentially when the competent ignition source came to be present and interact with the fuel
(4) How and sequentially when the competent ignition source transferred its heat energy to the fuel, causing ignition
(5) How safety devices and features designed to prevent fire from occurring operated or failed to operate *(see Chapter 25)*
(6) 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
(7) 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

19.4.4.3 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.

(1) Diffuse fuel explosions and flash fires.
(2) 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)*
(3) When there are multiple fires *(see Chapter 23)*
(4) When trailers are observed *(see Chapter 23)*
(5) The fire was observed or recorded at or near the time of inception or before it spread to a secondary fuel

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Δ **19.5 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.

Δ **19.5.1** 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.

Δ **19.5.2** 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.

19.5.3 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.

19.5.4 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.

19.6 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