Chapter 4 Basic Methodology

4.1* Nature of Fire Investigations. Afire 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. With few exceptions, the proper methodology for a fire or explosion investigation is to first determine and establish the origin(s), then investigate the cause: circumstances, conditions, or agencies that brought the ignition source, fuel, and oxidant together.

4.2 Systematic Approach. The systematic approach recommended is that of the scientific method, which is used in the physical sciences. This method provides for the organizational and analytical process desirable and necessary in a successful fire investigation.

4.3 Relating Fire Investigation to the Scientific Method. The scientific method *(see Figure 4.3)* is a principle of inquiry that forms a basis for legitimate scientific and engineering processes, including fire incident investigation. It is applied using the following steps outlined in 4.3.2 through 4.3.9.

Recognize the need
(identify the problem)
Analyze the data
Test the hypothesis
(deductive reasoning)
Scientific Method
Define the problem
Collect data
Develop a hypothesis
(inductive reasoning)
Select final hypothesis

FIGURE 4.3 Use of the Scientific Method.

4.3.1 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.

4.3.2 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.

4.3.3 Collect Data. Facts about the fire incident are 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.

4.3.4* 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.

4.3.5* Develop a Hypothesis (Inductive Reasoning). Based on the data analysis, the investigator produces a hypothesis, or 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.

4.3.6* Test the Hypothesis (Deductive Reasoning). The investigator does not have a valid hypothesis unless it 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 his or her hypothesis to all the known facts as well as the body of scientific knowledge associated with the phenomena relevant to the specific incident. A hypothesis can be tested either physically by conducting experiments or analytically by applying scientific principles in “thought experiments.” When relying on experiments or research of others, the investigator must ensure that the conditions and circumstances are sufficiently similar. When the investigator relies on previously conducted research, references to the research relied upon should be noted. If the hypothesis cannot be supported, it should be discarded and alternate hypotheses should be developed and tested. This may include 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.

4.3.6.1* Any hypothesis that is incapable of being tested 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.

4.3.7 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 scientific method has yielded testable hypotheses, which cannot be disproved by rigorous testing.

4.3.8 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.

4.3.9* Confirmation Bias. Different hypotheses may be compatible with the same data. When using the scientific method, testing of hypotheses should be designed to disprove the hypothesis. Confirmation bias occurs when the investigator instead tries to prove the hypothesis. This can result in failure to consider alternate hypotheses. A hypothesis can be said to be valid only when rigorous testing has failed to disprove the hypothesis.

4.4 Basic Method of a Fire Investigation. Using the scientific method in most fire or explosion incidents should involve the steps shown in 4.4.1 through 4.4.6.

4.4.1 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.

4.4.2 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.

4.4.3 Conducting the Investigation.

4.4.3.1 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.

4.4.3.2 The actual investigation may include different steps and procedures, which will be determined by the purpose of the assignment. These steps and procedures are described in detail elsewhere in the document. 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.

4.4.3.3 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.

4.4.3.4 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.

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

4.4.5 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.

4.4.6 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.

4.5 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.

4.5.1 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:

(1) 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.

(2) 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."

4.5.2 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.

4.5.3 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.

4.6 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.

4.6.1 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.

4.6.1.1 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.

4.6.2 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.

4.6.2.1 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 *(see 4.3.8)*. 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.

4.6.3 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.

4.6.3.1 The methodologies used and the fire science relied on by an investigator are subject to peer review. For example, NFPA 921 is a peer-reviewed document describing the methodologies and science associated with proper fire and explosion investigations.

4.6.3.2 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.

4.7 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.

A.4.1 For additional information, see the following publications:Cooke, R. A., and R. H. Ide. 1985. *Principles of Fire Investigation.*
Gloucestershire, UK: Institution of Fire Engineers, pp. 135–137.
DeHaan, J. D. 1997. *Kirk's Fire Investigation*. 4th ed. Upper Saddle River, NJ: Brady/Prentice-Hall, Inc.
Kennedy, J., and P. Kennedy. 1985. *Fires and Explosions—Determining Cause and Origin*. Chicago, IL: Investigations Institute.

A.4.3.4 Additional guidance can be found in ASTM E 678, *Standard Practice for Evaluation of Technical Data*.

A.4.3.5 The inductive method is the reasoning process by which a person starts from a particular experience and proceeds to generalizations. The person may start with, “All apples I have eaten were sweet.” From this he or she induces that apples are sweet. But the next apple may not be sweet. The inductive method leads to probabilities, not certainties. It is the basis of the common sense upon which persons act. It is also used in scientific discovery. Scientists use both induction and deduction. In deduction, scientists begin with generalizations. They deduce particular assertions from them. They might test their assertions by experiments, then confirm, revise, or reject their original generalizations. Using only deduction, people would ignore experience. Using only induction, they would ignore relationships among facts. By combining these methods, science unifies theory and practice.

A.4.3.6 This discussion is meant to specifically allow for logicbased “thought experiments.” In such an experiment, one sets up a premise and tests it against the data. An example of a thought experiment is, “If the door was closed during the fire, then there should be mirror-image patterns on the matching surfaces of the hinges.” It is not necessary to burn the door in the open position and in the closed position and compare results. The finding of mirror-image patterns, combined with the investigator’s knowledge, allows for conclusions to be made about many aspects of the fire without the need for a physical experiment. Deductive logic in the design and implementation of the thought experiment, however, is still a requirement for valid hypothesis testing.

The deductive method is the process of reasoning from which we draw conclusions by logical inference from given premises. If we begin by accepting the propositions that “all Greeks have beards” and that “Zeno is a Greek,” we may validly conclude, “Zeno has a beard.” We refer to the conclusions of deductive reasoning as valid, rather than true, because we must distinguish clearly between that which follows logically from other statements and that which is the case. Starting premises may be articles of faith or assumptions. Before we can consider the conclusions drawn from these premises as valid, we must show that they are consistent with each other and with the original premise. Mathematics and logic are examples of disciplines that make extensive use of the deductive method. The scientific method requires a combination of induction and deduction.

A.4.3.6.1 Vaughn, Lewis, *The Power of Critical Thinking, Effective Reasoning About Extraordinary Claims*, 2nd ed. Oxford University Press, New York/Oxford, 2008; Damer, Edward, T. *Attacking Faulty Reasoning. A Practical Guide to Fallacy-Free Thinking*, 4th ed., Wadsworth Thomson Learning, Belmont, CA, 2001. Kahane, Howard and Cavender, Nancy, *Logic and Contemporary Rhetoric, The Use of Reason in Everyday Life*, 9th ed.Wadsworth-Thomson Learning, Belmont, CA, 2002.

A.4.3.9 For a discussion of concrete examples of confirmation bias and its potential for causing erroneous interpretations of data, see Wason, P. C.(1960)