NFPA 1033 List of 16 Part 1: Understanding Topics 1 to 4

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This FISC submission begins a series of four articles addressing the of 16 topics listed in section 1.3.7 of NFPA 1033 - Standard for Professional Qualifications for Fire Investigator – of which investigators must have an up-to-date knowledge, beyond the high school level. These topics are:

(1) Fire science
(2) Fire chemistry
(3) Thermodynamics
(4) Thermometry
(5) Fire dynamics
(6) Explosion dynamics
(7) Computer fire modeling
(8) Fire investigation
(9) Fire analysis
(10) Fire investigation methodology
(11) Fire investigation technology
(12) Hazardous materials
(13) Failure analysis and analytical tools
(14) Fire protection systems
(15) Evidence documentation, collection, and preservation
(16) Electricity and electrical systems

Four of these 16 topics will be addressed in each submission. The intent of the FISC Committee is to provide the reader with resources to gain the requisite knowledge, and the ability to better articulate that knowledge, of these topics "beyond the high school level". Any opinions expressed in this series are those of the FISC and do not necessarily reflect the opinions of the National Fire Protection Association, the NFPA Technical Committee on Fire Investigations, The NFPA Technical Committee on Fire Investigator Professional Qualifications, or the International Association of Arson Investigators, Inc.

For each topic we will provide the relevant definition; a brief overview of the subject; additional resources readily available to learn about the topic; and, where applicable, suggestions on how to demonstrate that your learning is beyond the high school level. A college degree, however, is not the only way to gain information that is beyond the high school level.

NFPA 1033 is entitled Standard for Professional Qualifications for Fire Investigator and, as such, specifies what a person must be able to do (i.e. the job performance requirements – JPRs) to qualify as a fire investigator in both the public and private sectors. It also specifies the requisite knowledge a person must possess. When a fire event is subject to litigation, the investigator will likely have to demonstrate they do in fact possess the requisite knowledge before their origin and cause opinions will be accepted by the court.

While this series will point the motivated investigator to resources available to obtain, at least, the minimum level of required knowledge, the actual learning is up to the individual investigator. Why is it important to possess a minimum level of knowledge and demonstrate that the knowledge is current? The reasons are many but, as this is an IAAI publication, consider the IAAI Code of Ethics.

Consistent with the requirements of NFPA 1033, the IAAI Code of Ethics requires not only a minimum level of subject matter expertise but also continuing education; "I will regard it my duty to know my work thoroughly. It is my further duty to avail myself of every opportunity to learn more about my profession."1

NFPA 1033, as a Standard, requires that "The fire investigator shall remain current in the topics listed in section 1.3.7 by attending formal education courses, workshops and seminars and/or through professional publications and journals."2 Reading the IAAI Fire & Arson Investigator Journal demonstrates, to some extent, your commitment to continuing education.

The 2017 edition of NFPA 921 was updated to include significant additions intended to provide investigators the knowledge required by NFPA 1033, specifically regarding the 16 topics in section 1.3.7. All references to NFPA 921 in this article are to the 2017 edition.

Demonstrating that you have the requisite knowledge involves more than memorizing definitions. A competent fire investigator must be able to properly apply their knowledge, explain how that knowledge was applied to a set of facts (or to hypothetical situations), and articulate their work in a litigation setting. Expect to have to apply your knowledge to hypothetical questions from an opposing attorney.

1) Fire Science

Fire science is defined as, "the body of knowledge concerning the study of fire and related subjects (such as combustion, flame, products of combustion, heat release, fire and explosion chemistry, fire and explosion dynamics, thermodynamics, kinetics, fluid mechanics, fire safety) and their interaction with people, structures, and the environment."3

Fundamental to fire science are the concepts of energy, power (energy transfer per unit time measured in Joules/ second or Watts), and heat flux (rate of heat transfer to a surface or area measured in kW/m2). New information was included in the 2017 edition of NFPA 921 to specifically to address the 1033 list, including an expanded discussion of energy, power and heat flux.

Energy is a property of matter that manifests as an ability to perform work, either by moving over a distance against a force or by transferring heat. Energy can be changed in form (e.g., from chemical to mechanical energy), or transferred to other matter, but it can neither be created nor destroyed. Energy is measured in joules (J), calories (cal), or British thermal units (Btu).4

Power is a property that describes energy released per unit time. The same amount of energy is required to carry a load up a flight of stairs whether the person carrying it walks or runs, but more power is needed for running because the work is done in a shorter amount of time. Raising the temperature of a volume of water requires the same amount of energy whether the temperature increase takes place in 10 sec. or in 10 min. Raising the temperature more quickly requires that the energy be transferred more quickly. Power is measured in joules per second (J/s) or watts (W).5

Heat flux is a term that describes the amount of power per unit area. Heat flux is measured in kW/m2 or W/cm2.6

The foundation for the application of fire science to fire investigation is in the scientific method.

As can be seen in the definition, fire science is a broad topic and incorporates several of the 16 topics into its definition (e.g., fire chemistry, explosion chemistry, fire dynamics, thermodynamics). The specific inclusion of some of these fire science components as a separate topic is not intended to complicate the life of the fire investigator, but to emphasize the importance of that specific subject matter to the fire investigation process.

NFPA 921 defines fire science in section 3.3.77. Chapter 4 is entirely devoted to the scientific method and Chapter 5 covers Basic Fire Science.

The investigator must be able to articulate the steps of the scientific method in the proper order and explain each step in detail. The investigator must also be able to articulate the meaning of concepts such as energy, heat transfer, heat flux, power and work with the relevant units of measure.

2) Fire Chemistry

Fire chemistry is defined as, "the study of chemical processes that occur in a fire, including changes of state, decomposition, and combustion."7 The remaining sub-sections of chapter 5, section 2, go into greater detail about each aspect of this definition.

Chemistry is one of the physical sciences governed by the "laws of nature". For combustion to occur there must be a fuel, a heat source, an oxidizing agent, and an uninhibited chemical chain reaction (Fire Tetrahedron). In most cases encountered by the fire investigator, the first fuel ignited will have been in the solid phase when it was exposed to the heat source. The hypothesized ignition source must be able to, through heat transfer, convert the fuel into a gas/vapor before ignition can occur (e.g., pyrolysis). These changes in the state of a material and the subsequent oxidation reaction (fire) are the subject of fire chemistry.

Combustion is a chemical reaction consisting of rapid uninhibited oxidation (recall the definition of fire) during which oxygen molecules react with fuel molecules. This chemical reaction releases energy in the form of heat and light, that had been stored within the molecules. The released heat energy performs work by converting other items (target fuels) into ignitible form so the uninhibited chain reaction can continue.

Chapter 5 of NFPA 921 provides a discussion of fire chemistry in section 5.2 et. al.

The investigator should be able to explain the general form of a combustion reaction: hydrocarbon + oxygen carbon dioxide + water. It would also benefit the investigator to be able to explain (balance) a simple oxidation reaction equation, using hydrogen as an example, during which the burning of hydrogen in air produces water. The balanced equation describing this reaction is $2H_2 + O_2$ $2H_2O$. That tells us that 2 molecules of hydrogen (H2) react with 1 molecule of oxygen (O_2) to produce 2 molecules of water (H_2O).

Application of the principles pertaining to the chemistry of fire are essential for the development and testing of fire cause hypotheses.

3) Thermodynamics

Thermodynamics is defined as, "The branch of physics that deals with the relationship between heat and other forms of energy."8

The NFPA 921 definition does not provide the fire investigator with a way to practically apply thermodynamics to fire investigation. Thermodynamics can be thought of as how heat performs work. In high school physics we learned that work was required to move something. Work, in the context of fire, is more difficult to visualize.

Work is required to transfer heat. Heat transfer is what affects such things as fire chemistry (converting fuels to a gas or vapor), the rate at which pyrolysis occurs, heat release rate, time to flashover, and more.

Thermodynamics is defined in section 3.3.187 and certain aspects are presented within Chapters 5 and 6, particularly in the sections dealing with energy, power, heat transfer, heat release rate and flame height.

Chapter 5 also stresses the importance of this subject matter in section 5.1.1, "It is important that the fire investigator understands the basic concepts of energy, power and heat flux and how the units of measurement for each are used to describe the behavior of fire."

For the field fire investigator basic principles of thermodynamics will affect fire dynamics analyses, hypothesis development and testing.

continued on page 42

4) Thermometry

Thermometry is defined as, "The study of the science, methodology, and practice of temperature measurement."9

There are several systems for measuring temperature. There are the empirical scales (e.g., Fahrenheit, Celsius) and thermodynamic scales (e.g., Rankine, Kelvin). Thermodynamic scales are also known as Absolute scales. All use the "degree" as the unit of measure of temperature, which is the relative hotness or coldness of something. The "size" of the degree differs between the various temperature scales.

The empirical scales use the boiling and freezing points of water as references. In the Fahrenheit scale, water freezes at 32°F and boils at 212°F. In the Celsius scale water freezes at 0°C and boils at 100°C. Obviously, Fahrenheit degrees are "smaller" because there are more of them (180) between boiling and freezing than in the Celsius scale (100).

The thermodynamic scales use degrees Kelvin and degrees Rankine. Kelvin correlates to Celsius and Rankine correlates to Fahrenheit. Oversimplified, absolute zero is the lowest temperature that is theoretically possible. At absolute zero, internal molecular motion (heat) is virtually non-existent. On the Kelvin scale absolute zero is equivalent to –273.15°C. On the Rankine scale absolute zero is equivalent to –459.67°F.

NFPA 921 defines thermometry in section 3.3.188 and provides additional discussion in section 5.5.5.

Thermometry is not a consideration on the fire scene but can be a factor in post scene analysis, particularly if the investigator will be performing mathematical calculations. Fire science calculations will require the use of the SI units and can require use of the Thermodynamic scales. While memorization of the conversion formulae is not required, the investigator must be able to convert between the scales. Consistency of units is critical in mathematical calculations. Knowing where to find temperature scale conversion formulae and basic fire science calculations is essential. Table 5.4.4.3.3 provides the conversion formulae.

Additional Resources

NFPA 921 contains annexes (A, B and C) at the back of the book. An asterisk next to a section number in the body of NFPA 921 indicates there is annex material on the subject. The annexes provide direction to other sources of information on the topic at hand such as research papers, studies or texts. Such writings provide more detail than can be presented in NFPA 921 and are valuable resources for the investigator seeking to meet the NFPA 1033 standard.

Additionally, the IAAI's on-line training platform, www.CFITrainer.net,10 has 64 outstanding modules, many addressing the 16 topics of requisite knowledge. Specifically related to the topics in this article are the following modules:

- Understanding Fire Through the Candle Experiments
- Introduction to Fire Dynamics and Modeling
- Fire Dynamics Calculations
- A Ventilation Focused Approach to the Impact of Building Structures and Systems on Fire Development
- Thermometry, Heat and eat Transfer
- Postflashover Fires

Further, www.CFITrainer.net has listed as "upcoming" a program on "Fire Chemistry" specifically addressing the requirements of 1033 Section 1.3.7.

Besides NFPA 921 and www.CFITrainer.net, there are other resources with sections on the topics covered in this column. See, for example, Kirk's Fire Investigation, 8th edition,11 Fire Investigator Principles and Practice to NFPA 921 and 1033, 4th edition,12 and Scientific Protocols for Fire Investigation, 2nd edition.13

Conclusion

By virtue of the legal systems within most fire investigators operate, fire investigators must qualify as experts. Webster defines "expert" as a person "having, involving, or displaying special skill or knowledge derived from training or experience."14 Learning the requisite knowledge of the 16 topics in NFPA 1033 does not require a college degree. It does require personal commitment and effort. The resources necessary are readily available. NFPA 921 is the place to start. The successful investigator will not let it end there.

Over the next three months, before the next edition of this Journal is published, a review of the above-listed CFITrainer.net modules would be helpful to fire investigators and others striving to learn the first four topics in NFPA 1033's List of 16. In the next edition of the FISC Bulletin Board, we will be exploring the next four topics in the list: fire dynamics, explosion dynamics, computer fire modeling and fire investigation.

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Endnotes

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