DELETED

First Revision No. 1-NFPA 921-2015 [Global Input]

Change "ignitable" to "ignitible" throughout the document.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Submittal Date: Mon May 11 11:18:09 EDT 2015

Committee Statement

Committee Statement: The term is changed to be consistent with NFPA's Glossary of Terms.
Response Message:
Public Input No. 147-NFPA 921-2014 [Global Input]

First Revision No. 156-NFPA 921-2015 [Detail]

27.4.2.6.1

Vehicles may be equipped from the OEM with High Intensity Discharge (HID) headlamps. The Xenon bulbs used in HID lighting systems produce three times the light output of standard halogen headlamps with less operating energy. HID headlamps require a high voltage ignition source to start, typically up to 25,000 volts, but only 40-90 volts, depending on the system, to operate once the initial arc has formed. The normal 12 volts DC from the vehicle's electrical system is stepped up and controlled by an igniter module and inverter (ballast), which also converts the voltage to AC, which is necessary to operate the HID headlamps. The ballast then adjusts the voltage and current frequency to operating requirements. Aftermarket HID conversion kits are commonly available and, if installed, may cause overloading of the OEM wiring or have other installation issues that may result in a fire within the headlight assembly.

Supplemental Information

File Name	Description
921_FR_156_edited.docx	For staff use

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
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Submittal Date: Tue Jun 09 15:22:36 EDT 2015

Committee Statement

Committee Statement: The insertion of this sentence serves to enhance this section by adding relative, accurate information.

Response Message:

Public Input No. 284-NFPA 921-2015 [New Section after 27.4.2]

27.4.2.6.1

Vehicles may be equipped by the OEM with high-intensity discharge (HID) headlamps. The xenon bulbs used in HID lighting systems produce three times the light output of standard halogen headlamps with less operating energy. HID headlamps require a high-voltage ignition source to start, up to 25,000 volts, but, depending on the system, only 40–90 volts to operate once the initial arc has formed. The normal 12 volts dc from the vehicle's electrical system is stepped up and controlled by an igniter module and inverter (ballast), which also converts the voltage to the necessary ac to operate the HID headlamps. The ballast then adjusts the voltage and current frequency to operating requirements. Aftermarket HID conversion kits are commonly available and, if installed, could overload the OEM wiring or cause other installation issues that could result in a fire within the headlight assembly.

First Revision No. 157-NFPA 921-2015 [Detail]

27.14.1.6.1 Overcurrent Protection of Diesel Electrical Systems.

In many of the high current systems used in heavy trucks, fusible links are often used to provide overcurrent protection for conductors in the event of overloading or short circuit conditions. Fusible links are typically found in the positive side of battery/starter circuits, but may also may be found in the negative (ground) side. In the event a positive battery cable or alternator positive cable comes in contact with the chassis/engine ground, short circuit currents flow through the negative side fusible link as it returns to the negative starter post and thus opens to prevent further current flow. The investigator should document connections to the positive starter post, the starter ground post, and the battery negative posts, in the battery box, in order to evaluate their effect on the functioning of the negative fusible link. These fusible links may not show surface heat distress but still may have opened internally. For any fusible link, an ohmmeter can be used to verify the condition.

Supplemental Information

File Name	Description
921_FR_157_edited.docx	FR 157 copyedited

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Submittal Date: Tue Jun 09 15:36:16 EDT 2015

Committee Statement

Committee Statement: The creation of a new section, with new text, serves to enhance this chapter by adding new, relative information and guidance for the reader.

Response Message:

Public Input No. 185-NFPA 921-2014 [Section No. 27.14.1.6]

27.14.6.1 Overcurrent Protection of Diesel Electrical Systems.

In many of the high-current systems used in heavy trucks, fusible links are often used to provide overcurrent protection for conductors in the event of overloading or short circuit conditions. Fusible links are typically found in the positive side of battery/starter circuits, but may also be found in the negative (ground) side. In the event a positive battery cable or alternator positive cable comes in contact with the chassis/engine ground, short circuit currents flow through the negative side fusible link as it returns to the negative starter post and thus opens to prevent further current flow. The investigator should document connections to the positive starter post, the starter ground post, and the battery negative posts in the battery box to evaluate their effect on the functioning of the negative fusible link. These fusible links may not show surface heat distress but still may have opened internally. For any fusible link, an ohmmeter can be used to verify the condition.

First Revision No. 159-NFPA 921-2015 [Detail]

Add the following new section after 23.9.6.3:

23.9.6.4 Hybrid Dust Explosions.

The presence of flammable gases and vapors, even at concentrations less than the lower flammable limit (LFL) of the flammable gases and vapors, adds to the violence of a dust-air combustion. The resulting dust-vapor mixture is called a hybrid mixture and is discussed in Eckhoff, *Dust Explosions in the Process Industries*. In certain circumstances, hybrid mixtures can be deflagrable, even if the dust is below the MEC and the vapor is below the LFL. Furthermore, dusts determined to be nonignitible by weak ignition sources can sometimes be ignited when part of a hybrid mixture. An example of a hybrid mixture is a mixture of methane, coal dust, and air.

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Committee Statement

Committee Statement: New material describes an issue of flammability of hybrid mixtures not previously covered.
Response Message:
Public Input No. 55-NFPA 921-2014 [New Section after 23.9.6.2]

First Revision No. 2-NFPA 921-2015 [Section No. 1.2.2]

1.2.2

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

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Committee Statement

Committee Statement: The committee agrees the additional wording accurately describes what is needed for the compilation of fire statistics. Also, see Chapter 21, section 21.1.

Response Message:

Public Input No. 152-NFPA 921-2014 [Section No. 1.2.2]

First Revision No. 152-NFPA 921-2015 [Sections 2.1, 2.2, 2.3, 2.4]

2.1 General.

The documents or portions thereof listed in this chapter are referenced within this guide ~~and shall be considered part of the requirements of this document~~ .

2.2 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2013 edition.

NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes,* 2016 edition.

NFPA 13R, *Standard for the Installation of Sprinkler Systems in Low-Rise Residential Occupancies,* 2013 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* ~~2012~~ 2015 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 2011 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* ~~2011~~ 2015 edition.

NFPA 54, *National Fuel Gas Code,* ~~2012~~ 2015 edition.

NFPA 58, *Liquefied Petroleum Gas Code,* 2014 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2013 edition.

NFPA 70®, *National Electrical Code®,* 2014 edition.

NFPA 72®, *National Fire Alarm and Signaling Code,* 2013 edition.

NFPA 77, *Recommended Practice on Static Electricity,* 2014 edition.

NFPA *101®*, *Life Safety Code®,* ~~2012~~ 2015 edition.

NFPA 120, *Standard for Fire Prevention and Control in Coal Mines,* ~~2010~~ 2015 edition.

NFPA 170, *Standard for Fire Safety and Emergency Symbols,* ~~2012~~ 2015 edition.

NFPA 220, *Standard on Types of Building Construction,* ~~2012~~ 2015 edition.

NFPA 260, *Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture,* 2013 edition.

NFPA 261, *Standard Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes,* 2013 edition.

NFPA 302, *Fire Protection Standard for Pleasure and Commercial Motor Craft,* ~~2010~~ 2015 edition.

NFPA 303, *Fire Protection Standard for Marinas and Boatyards,* 2011 edition.

NFPA 400, *Hazardous Materials Code,* 2013 edition.

NFPA 501, *Standard on Manufactured Housing,* 2013 edition.

NFPA 555, *Guide on Methods for Evaluating Potential for Room Flashover,* 2013 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2013 edition.

NFPA 1033, *Standard for Professional Qualifications for Fire Investigator,* 2014 edition.

NFPA 1144, *Standard for Reducing Structure Ignition Hazards from Wildland Fire,* 2013 edition.

NFPA 1192, *Standard on Recreational Vehicles,* ~~2011~~ 2015 edition.

NFPA 1194, *Standard for Recreational Vehicle Parks and Campgrounds,* 2014 edition.

NFPA 1403, *Standard on Live Fire Training Evolutions,* 2012 edition.

NFPA 1404, *Standard for Fire Service Respiratory Protection Training,* 2013 edition.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* 2013 edition.

NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting,* 2013 edition.

NFPA 1977, *Standard on Protective Clothing and Equipment for Wildland Fire Fighting,* 2011 edition.

NFPA 1852, *Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA),* 2013 edition.

NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services,* 2013 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2015 edition.

Fire Protection Handbook, 5th (1981), ~~16th (1986),~~ 17th (1991), 18th (1997), 19th (2003), and 20th (2008) edition.

Fire Protection Guide to Hazardous Materials, ~~2010~~ 2015 edition.

National Fuel Gas Code Handbook, ~~2012~~ 2015 edition.

The SFPE Engineering Guide to Human Behavior in Fire, 2003 edition.

The SFPE Handbook of Fire Protection Engineering, Society of Fire Protection Engineers, Quincy, MA, 2008 edition.

SPP 51 Flash Point Index of Trade Name Liquids, 1978 edition.

2.3 Other Publications.

2.3.1 ABYC Publications.

American Boat and Yacht Council, 613 Third Street, Suite 10, Annapolis, MD 21403.

ABYC A-3, *Galley Stoves*, 2007.

ABYC A-7, *Liquid and Solid Fueled Boat Heating Systems*, ~~2006~~ 2014 .

ABYC A-26, *LPG and CNG Fueled Appliances*, ~~2006~~ 2012 .

ABYC A-30, *Cooking Appliances with Integral LPG Cylinders*, ~~2006~~ 2013, RFI .

ABYC E-11, *AC & DC Electrical Systems on Boats* , 2012, RFI.

ABYC H-24.13, *Gasoline Fuel Systems*, ~~2005~~ 2012 .

ABYC H-32, *Ventilation of Boats Using Diesel Fuel*, ~~2007~~ 2013 reaffirmed .

ABYC P-1, *Installation of Exhaust Systems for Propulsion and Auxiliary Engines* , ~~2002~~ 2014 .

2.3.2 ANSI Publications.

American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI Z400.1/ Z129.1, ~~*Precautionary Labeling of Hazardous Industrial Chemicals*~~ *Hazardous Workplace Chemicals — Hazard Evaluation and Safety Data Sheet and Precautionary Labeling* , ~~2000~~ 2010 .

ANSI Z400.1, *Material Safety Data Sheets — Preparation*, 1998.

ANSI Z535.1, *Safety Color ~~Code~~* , ~~1998~~ 2006, reapproved 2011 .

ANSI Z535.2, *Environmental and Facility Safety Signs*, ~~1998~~ 2011 .

ANSI Z535.3, *Criteria for Safety Symbols*, ~~1998~~ 2011 .

ANSI Z535.4, *Product Safety Signs and Labels*, ~~1998~~ 2011 .

ANSI Z535.5, *Accident Prevention Tags*, 1998.

2.3.3 API Publications.

American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005-4070.

~~API/RP~~ API RP 2003, *Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents,* ~~1991~~ 7th edition, 2008 .

API RP 2216, *Ignition Risk of Hydrocarbon Vapors by Hot Surfaces in the Open Air,* 3rd edition, 2003, reaffirmed 2010 .

2.3.4 ASME Publications.

American Society of Mechanical Engineers, ~~Three~~ Two Park Avenue, New York, NY 10016-5990.

Boiler and Pressure Vessel Code, 2013.

2.3.5 ASTM Publications.

ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D56, *Standard Test Method for Flash Point by Tag Closed Tester*, 2005 (2010).

ASTM D86, *Standard Test Method for Distillation of Petroleum*, ~~2011b~~ 2012 .

ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*, ~~2011~~ 2012b .

ASTM D93, *Standard Test Method for Flash Point by Pensky-Martens Closed Cup Tester*, ~~2011~~ 2015 .

ASTM D1230, *Standard Test Method for Flammability of Apparel Textiles*, 2010.

ASTM D1265, *Standard Practice for Sampling Liquefied Petroleum (LP) Gases, ~~(~~ Manual Method~~)~~* , 2011.

ASTM D1310, *Standard Test Method for Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus*, ~~2001 (2007)~~ 2014 .

ASTM D1929, *Standard Test Method for Determining Ignition Temperature of Plastics*, ~~2011~~ 2014 .

ASTM D2859, *Standard Test Method for Flammability of Finished Textile Floor Covering Materials*, 2006 (2011).

ASTM D2887, *Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography*, ~~2008~~ 2014 .

ASTM D3065, *Standard Test Methods for Flammability of Aerosol Products*, 2001 (~~2006~~ 2013).

ASTM D3828, *Standard Test Methods for Flash Point by Small Scale Closed Tester*, ~~2009~~ 2012a .

ASTM D4809, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)*, ~~2009a~~ 2013 .

ASTM D5305, *Standard Test Method for Determination of Ethyl Mercaptan in LP-Gas Vapor*, ~~1997 (2007)~~ 2012 .

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, ~~2011c~~ 2015 .

ASTM E108, *Standard Test Method for Fire Tests of Roof Coverings*, 2011.

ASTM E119, *Standard Methods for Fire Tests of Building Construction and Materials*, ~~2011a~~ 2014 .

ASTM E603, *Standard Guide for Room Fire Experiments*, ~~2007~~ 2013 .

ASTM E648, *Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*, ~~2010 e1~~ 2014c .

ASTM E659, *Standard Test Method for Autoignition Temperature of Liquid Chemicals*, ~~1978 (2005)~~ 2014 .

ASTM E681, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gasses)* , 2009.

ASTM E800, *Standard Guide for Measurement of Gases Present or Generated During Fires*, ~~2007~~ 2014 .

ASTM E860, *Standard Practice for Examining and Preparing Items that Are or May Become Involved in Criminal or Civil Litigation*, ~~2007~~ (2013)e1 .

ASTM E906/E906M , *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using a Thermopile Method* , ~~2010~~ 2014 .

ASTM E1188, *Standard Practice for Collection and Preservation of Information and Physical Items by a Technical Investigator*, 2011.

ASTM E1226, *Standard Test Method for ~~Pressure and Rate of Pressure Rise for Combustible Dusts~~ Explosibility of Dust Clouds* , ~~2010~~ 2012a .

~~ASTM E1352, *Standard Test Method for Cigarette Ignition Resistance of Mock-up Upholstered Furniture Assemblies,* 2008a.~~

~~ASTM E1353, *Standard Test Methods for Cigarette Ignition Resistance of Components of Upholstered Furniture,* 2008a e1.~~

ASTM E1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, ~~2011b~~ 2014e1 .

ASTM E1355, *Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models* , 2012.

ASTM E1459, *Standard Guide for Physical Evidence Labeling and Related Documentation*, ~~1992 (2005)~~ 2013 .

ASTM E1491, *Standard Test Method for Minimum Autoignition Temperature of Dust Clouds* , 2006 (2012).

ASTM E1492, *Standard Practice for Receiving, Documenting, Storing, and Retrieving Evidence in a Forensic Science Laboratory* , 2011.

ASTM E1618, *Standard Guide for ~~Ignitable~~ Ignitible Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography–Mass Spectrometry*, ~~2011~~ 2014 .

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air* , 2003 (2013).

ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers* , 2009 (2013).

ASTM E2067. , *Standard Practice for Full-Scale Oxygen Consumption Calorimetry Fire Tests*, ~~2008~~ 2012 .

2.3.6 ~~FMC~~ FM Global Publications.

FM Global, ~~1301 Atwood Avenue~~ 270 Central Avenue, P.O. Box 7500 , Johnston, RI 02919.

FMC Product Safety Sign and Label System Manual, 1985.

2.3.7 Military Standards Publications.

SAE, 1620 I Street, NW, Suite 210, Washington, DC 20006.

~~MIL-Std-202F~~ MIL-STD-202G , *Test Method for Electronic and Electrical Components Parts* , (w. Change 2) 2013 .

2.3.8 SAE International Publications.

SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J2578, *Recommended Practice for General Fuel Cell Vehicle Safety*, ~~2009~~ 2014 .

2.3.9 UL Publications.

Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

~~ANSI/~~ UL 263, *Standard for Safety Fire Tests of Building Construction and Materials,* 14th edition, 2011, revised 2014 .

~~ANSI/~~ UL 969, *Standard for Marking and Labeling Systems*, 4th edition, 1995, ~~revised 2008~~ revised 2014 .

UL 1500, *Standard for Safety Ignition Protection Test for Marine Products*, 3rd edition, 1997, revised 2007.

2.3.10 USFA Publication.

U.S. Fire Administration, 16825 S. Seton Avenue, Emmitsburg, MD 21727.

"Minimum Standards on Structural Fire Fighting Protective Clothing and Equipment," 1992.

2.3.11 U.S. Government Publications.

U.S. Government Printing Office, Washington, DC 20402.

"Consumer Safety Act" (15 USC, Sections 2051–2084, and Title 16, Code of Federal Regulations, Part 1000).

"Federal Food, Drug and Cosmetic Act" [15 USC, Section 321 (m), and Title 21, Code of Federal Regulations, Part 600].

"Flammable Fabrics Act" (15 USC, Sections 1191–1204 and Title 16, Code of Federal Regulations, Parts 1615, 1616, and 1630–1632.

Hazardous Substances Act (15 USC, Section 1261 et seq., and Title 16, Code of Federal Regulations, Part 1500).

NIOSH Pocket Guide to Chemical Hazards, 2010.

OSHA Regulations (Title 29, Code of Federal Regulations, Part 1910).

Title 24, Code of Federal Regulations, Part 3280, "Manufactured Home Construction and Safety Standards (HUD Standard.)"

Title 29, Code of Federal Regulations, Part 1910, "Federal Hazards Communication Standard."

Title 33, Code of Federal Regulations, Part 173, "Vessel Numbering and Casualty and Accident Reporting."

Title 33, Code of Federal Regulations, Part 181, "Manufacturer Requirements."

Title 33, Code of Federal Regulations, Part 183, "Boats and Associated Equipment."

Title 46, Code of Federal Regulations, Chapter 1, subchapter C, "Shipping."

~~Title 49, Code of Federal Regulations, Part 129.625, "Fire Related Human Behavior," U.S. Fire Administration, 257, 1994.~~

Title 49, Code of Federal Regulations, Part 173, "General Requirements for Shipments and Packagings."

Title 49, Code of Federal Regulations, Part 178, "Shipping Container Specifications."

Title 49, Code of Federal Regulations, Part 192, "Transportation of Natural and Other Gases by Pipeline Minimum Safety Standards."

Title 49, Code of Federal Regulations, Part 568, Vehicles Manufactured in Two or More Stages."

United States Federal Rules of Evidence as amended through 2011.

U.S. Senate Committee on Government Operations, *Chart of the Organization of Federal Executive Departments and Agencies*.

2.3.12 Other Publications.

Babrauskas, V. *Ignition Handbook*. Issaquah, WA: Fire Science and Technology, Inc., 2003.

Baumeister, T., E. A. Avallone, and T. Baumeister III. *Mark's Standard Handbook for Mechanical Engineers*, 10th edition. New York, NY: McGraw-Hill, 1996.

Beyler, C. "Flammability Limits of Premixed and Diffusion Flames." In *SFPE Handbook of Fire Protection Engineering*, ed. P. DiNenno. Quincy, MA: National Fire Protection Association, 2002.

Braisie, N., and N. Simpson. "Guide for Estimating Damage," *Explosion Loss Prevention*, 1968.

Bull, J. P., and J. C. Lawrence. "Thermal Conditions to Produce Skin Burns," *Fire and Materials* 3(2) (1979): 100–05.

Bustin, W. M., and W. G. Duket. *Electrostatic Hazards in the Petroleum Industry*. London, UK: Research Studio Press, July 1983.

Cole, L. *The Investigation of Motor Vehicle Fires: A Guide for Law Enforcement, Fire Department and Insurance Personnel*, 3rd ed. Lincoln, NE: Lee Books, 1992.

Coltharp, D. R. "Blast Response Tests of Reinforced Concrete Box Structures," Department of Defense, 1983.

Crowl, D. A., and J. F. Louvar. Chemical Process Safety, 2nd ed. Englewood Cliffs, NJ: Prentice Hall, 2001.

Derkson, W. L., T. I. Monohan, and G. P. deLhery. "The Temperature Associated with Radiant Energy Skin Burns," *Temperature— Its Measurement and Control in Science and Industry* 3(3) (1963): 171–75.

Douglas, J. E., A. W. Burgess, and R. K. Ressler. *Crime Classification Manual*. New York, NY: Lexington Books, 1992.

Drysdale, D. *An Introduction to Fire Dynamics*. Chichester, UK: John Wiley and Sons, Third edition, 2011.

Drysdale, D. "Fire Dynamics," *ISFI Proceedings, International Symposium on Fire Investigation Science and Technology*. Sarasota, FL: National Association of Fire Investigators, 2006.

Eckhoff, R., *Dust Explosions in the Process Industries* , 3rd ed. Houston, TX: Gulf Professional Publishing, 2003.

Fang, J. B., and J. N. Breese, *Fire Development in Basement Rooms*. Gaithersburg, MD: National Institute of Standards and Technology, 1980.

Garner, B. A., and H. C. Black. *Black's Law Dictionary*, 7th ed. Saint Paul, MN: West Publishing Company, 1999.

Gieck, K., and R. Gieck. Engineering Formulas. New York, NY: McGraw-Hill, 1997.

Gottuck & White, *Liquid Fuel Fires SFPE Handbook of Fire Protection Engineering,* NFPA, 2002.

Grant, G., and D. Drysdale. "Numerical Modeling of Early Flame Spread in Warehouse Fires," *Fire Safety Journal* 24(3) (1995): 247–78.

Guide to Plastics (Plastics Handbook). New York, NY: McGraw-Hill, 1989.

~~Kennedy & Shanley, Report on the USFA Program for the Study of Fire Pattern, Interflam '96 Proceedings.~~

Hagglund, B., and S. Persson, *An Experimental Study of the Radiation from Wood Flames*. FOA Report C 4589-D6(A3). Stockholm, Sweden: Forsvarerts Forskningsanstalt, 1976.

Hilado, C. J. *Flammability Handbook for Plastics*, 4th ed. Lancaster, PA: Technomic Publishing, 1990.

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Krasny, J. *Cigarette Ignition of Soft Furnishings— A Literature Review With Commentary*. Washington, DC: Center for Fire Research, National Bureau of Standards, June 1987.

Kransny, J., W. Parker, and V. Babrauskas. *Fire Behavior of Upholstered Furniture and Mattresses*. Park Ridge, NJ: Noyes Publications, 2001.

LaPointe, N., C. Adams, and J. Washington. "Autoignition of Gasoline on Hot Surfaces," *Fire and Arson Investigator*, 2005.

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Lawson, J. *An Evaluation of Fire Properties of Generic Gypsum Board Products* (NBSIR 77-1265). Washington, DC: NIST, Center for Fire Research, 1977.

Lee, B. T. *Heat Release Rate Characteristics of Some Combustible Fuel Sources in Nuclear Power Plants.*

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Lide, D. R., ed. *Handbook of Chemistry and Physics*, 71st ed. Boca Raton, FL: CRC Press, 1990–1991.

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McRae, T. G., H. C. Goldwire, W. J. Hogan, and D. L. Morgan. "Effects of Large-Scale LNG/Water RPT Explosions," Department of Energy, 1984.

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Quintiere, J. “Surface Flame Spread.” In *SFPE Handbook of Fire Protection Engineering*, ed. P. DiNenno. Quincy, MA: National Fire Protection Association, 2002.

Saito, K., J. G. Quintiere, and F. A. Williams. “Upward Turbulent Flame Spread,” *Fire Safety Science.* International Association for Fire Safety Science, 1986. *Proceedings, 1st International Symposium*. C. E. Grant and P. J. Pagni, eds. New York, NY: Hemisphere Publishing Corp., pp. 75–86.

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Society of Fire Protection Engineers. *SFPE Handbook of Fire Protection Engineering,* ed. P. DiNenno. Quincy, MA: National Fire Protection Association, 2002.

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Wu, P., L. Orloff, and A. Tewarson. “Assessment of Material Flammability with the FG Propagation Model and Laboratory Test Methods,” Thirteenth Joint Panel Meeting of the UJNR Panel on Fire Research and Safety, Gaithersburg, MD, 1996.

2.4 References for Extracts in Advisory Sections.

NFPA 3, *Recommended Practice for Commissioning of Fire Protection and Life Safety Systems,* 2015 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2013 edition.

NFPA 53, *Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres,* 2011 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* ~~2014~~ 2013 edition.

NFPA 70®, National Electrical Code®, 2014 edition.

NFPA 72®, National Fire Alarm and Signaling Code, 2013 edition.

NFPA 318, *Standard for the Protection of Semiconductor Fabrication Facilities,* ~~2012~~ 2015 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2013 edition.

Supplemental Information

File Name	Description
Staff_only_FR_152_Chap_2.docx	1. Revised Chapter 2.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Submittal Date: Wed Jun 03 13:21:44 EDT 2015

Committee Statement

Committee Statement: The changes to Chapter 2 update all citations and edition dates for the industry codes, standards, recommended practices, and guides. The way each document is cited, including the document title, the manner of showing the edition date and edition number, as well as other related information, has been revised to conform to the way the document is cited on the publisher's website, subject to specific NFPA editorial rules for citations.

FM Global's address has been updated in accordance with information on its website.

Title 49, CFR, Part 129.625, "Fire Related Human Behavior," U.S. Fire Administration 257, 1994 has been removed because it can no longer be located in the Code of Federal Regulations.

Documents that are referenced in the body of Chapters 4 to 30 have been added to comply with requirements of the NFPA Manual of Style (i.e. NFPA 1033, ABYC E-11, ASTM E1355, and NIOSH Pocket Guide to Chemical Hazards have been added).

Section 2.1 "General" has been revised, replacing the current language with the mandatory language prescribed by the NFPA Manual of Style s.2.4.2.3.1.

Response Message:

First Revision No. 3-NFPA 921-2015 [New Section after 3.3]

3.3.68 Fire Area.
The boundary of fire effects within a scene in which the area of origin will be located. The fire area is characterized by identifying the border between damaged and undamaged areas, which are distinguishable by fire effects and patterns created by flame, heat, and smoke.

Submitter Information Verification

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Committee Statement

Committee Statement: The committee added definition to clarify the meaning of 'fire area'.
Response Message:
Public Input No. 177-NFPA 921-2014 [New Section after 3.3]

First Revision No. 4-NFPA 921-2015 [New Section after 3.3]

3.3.187 Thermodynamics.
The branch of physics that deals with the relationship between heat and other forms of energy.

Submitter Information Verification

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Committee Statement

Committee Statement: The committee added definition to clarify the meaning of ‘thermodynamics’.
Response Message:
Public Input No. 280-NFPA 921-2015 [New Section after 3.3]

First Revision No. 6-NFPA 921-2015 [New Section after 3.3]

3.3.106 Heat Transfer.
The exchange of thermal energy between materials through conduction, convection, and/or radiation.

Submitter Information Verification

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Committee Statement

Committee Statement: The committee added definition to clarify the meaning of 'heat transfer'.
Response Message:
Public Input No. 281-NFPA 921-2015 [New Section after 3.3]

First Revision No. 34-NFPA 921-2015 [New Section after 3.3.3]

3.3.4 Active Fire Protection System.
A system that uses moving mechanical or electrical parts to achieve a fire protection goal. [**3,** 2015]

Submitter Information Verification

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Committee Statement

Committee Statement: The committee has reorganized, clarified, and added images and photographs to Chapter 8 to improve the content. As a result the definition is necessary.
Response Message:

First Revision No. 19-NFPA 921-2015 [New Section after 3.3.51]

3.3.53 Energy.
A property of matter manifested as an ability to perform work, either by moving an object against a force or by transferring heat.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Submittal Date: Tue May 12 11:07:33 EDT 2015

Committee Statement

Committee Statement: NFPA 1033 requires that fire investigators understand fire dynamics, but NFPA 921 does define energy. The committee considered the existing NFPA Glossary of Terms definition, but believes this is a better definition because it more easily relates to fire.

Response Message:

First Revision No. 85-NFPA 921-2015 [New Section after 3.3.52]

3.3.55 Explosible.

A material with a pressure ratio (maximum pressure/pressure at ignition, in absolute units) equal to or greater than 2.0 in any test when tested using the explosibility or Go/No-Go screening test described in Section 13 of ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds* . [**68,** 2013]

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: The addition of specific terminology that was not included (2014) Edition of 921.
Response Message:

First Revision No. 7-NFPA 921-2015 [New Section after 3.3.53]

3.3.57 Explosion Dynamics.

Study of how chemistry, physics, fire science, engineering disciplines of fluid and solid mechanics, and heat transfer interact to influence explosion behavior.

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Submittal Date: Mon May 11 12:31:30 EDT 2015

Committee Statement

Committee Statement: The Committee is adding this definition to clarify the meaning of 'explosion dynamics'

Response Message:

Public Input No. 230-NFPA 921-2015 [New Section after 3.3.53]

First Revision No. 8-NFPA 921-2015 [New Section after 3.3.66]

3.3.71 Fire Effects.
The observable or measurable changes in or on a material as a result of a fire.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: The Committee is adding this definition to clarify the meaning of 'fire effects'.
Response Message:
Public Input No. 169-NFPA 921-2014 [New Section after 3.3.66]

First Revision No. 21-NFPA 921-2015 [Section No. 3.3.97]

3.3.103 Heat Flux.

The measure of the rate of heat transfer to a surface~~,~~ or an area, typically expressed in ~~kilowatts~~ kW /m^2~~, kilojoules/m^2 · sec, or Btu/ft^2 · sec~~ .

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: The committee believes this is a better definition of heat flux.
Response Message:

NFPA First Revision No. 87-NFPA 921-2015 [New Section after 3.3.101]

3.3.109* Hybrid Mixture.
An explosible heterogeneous mixture, comprising gas with suspended solid or liquid particulates, in which the total flammable gas concentration is ≥ 10 percent of the lower flammable limit (LFL) and the total suspended particulate concentration is ≥ 10 percent of the minimum explosible concentration (MEC). [**68,** 2013]

Supplemental Information

File Name	Description
FR_87_A.3.3.X.docx	1. New annex for definition.

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
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Committee Statement

Committee Statement: The addition of specific terminology that was not included (2014) Edition of 921.
Response Message:

A.3.3.X Hybrid Mixture. In certain processes, flammable gases can desorb from solid materials. If the solid is combustible and is dispersed in the gas-oxidant mixture, as can be the case in a fluidized bed dryer, a hybrid mixture can also result. (See NFPA 68 2013 6.2.3.)

First Revision No. 9-NFPA 921-2015 [Section No. 3.3.108]

3.3.116 Incendiary Fire.

A fire that is ~~deliberately set with the intent to cause the fire to occur~~ intentionally ignited in an area ~~where the fire~~ or under circumstances where and when there should not be a fire .

Submitter Information Verification

Submitter Full Name: Michael Wixted

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Committee Statement

Committee Statement: The committee is revising this definition to clarify the meaning of ‘incendiary fire’.

Response Message:

Public Input No. 19-NFPA 921-2014 [Section No. 3.3.108]

Public Input No. 222-NFPA 921-2014 [Section No. 3.3.108]

Public Input No. 299-NFPA 921-2015 [Section No. 3.3.108]

First Revision No. 86-NFPA 921-2015 [New Section after 3.3.120]

3.3.129 Minimum Explosible Concentration (MEC).
The minimum concentration of a combustible dust cloud that is capable of propagating a deflagration through a uniform mixture of the dust and air under the specified conditions of test. [**68,** 2013]

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: The addition of specific terminology that was not included (2014) Edition of 921.
Response Message:

First Revision No. 10-NFPA 921-2015 [Section No. 3.3.127]

3.3.136* Overload.

Operation of equipment in excess of normal, full-load rating or of a conductor in excess of rated ampacity that, ~~when~~ where it persists for a sufficient length of time would cause damage or dangerous overheating. ~~An overload current is usually but might not always be confined to the normal intended conductive paths provided by conductors and other electrical components of an electrical circuit. Operation of the equipment or wiring under current flow conditions leading to temperatures in excess of the temperature rating of the equipment or wiring.~~ A fault, such as a short circuit or ground fault, is not an overload .

Submitter Information Verification

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Committee Statement

Committee Statement: The committee is revising this definition to clarify the meaning of 'overload'.

Response Message:

Public Input No. 202-NFPA 921-2014 [Section No. A.3.3.127]

Public Input No. 201-NFPA 921-2014 [Section No. 3.3.127]

First Revision No. 35-NFPA 921-2015 [New Section after 3.3.128]

3.3.138 Passive Fire Protection System.
Any portion of a building or structure that provides protection from fire or smoke without any type of system activation or movement. [**3,** 2015]

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Committee Statement

Committee Statement: The committee has reorganized, clarified, and added images and photographs to Chapter 8 to improve the content. As a result the definition is necessary.
Response Message:

First Revision No. 20-NFPA 921-2015 [New Section after 3.3.131]

3.3.143 Power.
A property of a process, such as fire, which describes the amount of energy that is emitted, transferred, or received per unit time and is measured in joules per second (J/s) or watts (W).

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Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: NFPA 1033 requires that fire investigators understand fire dynamics, but NFPA 921 does define power. The committee considered the existing NFPA Glossary of Terms definition, but believes this is a better definition because it more easily relates to fire.

Response Message:

First Revision No. 11-NFPA 921-2015 [Section No. 3.3.132]

3.3.142 Point of Origin.

The exact physical location within the area of origin where a heat source and ~~the~~ a fuel first interact, resulting in a fire or explosion.

Submitter Information Verification

Submitter Full Name: Michael Wixted

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Committee Statement

Committee Statement: This is a grammatical change to clarify the text.

Response Message:

Public Input No. 173-NFPA 921-2014 [Section No. 3.3.132]

First Revision No. 22-NFPA 921-2015 [Section No. 3.3.141]

3.3.152 Radiant Heat.

Heat energy carried by electromagnetic waves that are longer than visible light waves and shorter than radio waves; radiant heat (electromagnetic radiation) increases the sensible temperature of any substance capable of absorbing the radiation, especially solid and opaque objects.

Submitter Information Verification

Submitter Full Name: Michael Wixted

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Committee Statement

Committee Statement: The word “visible” is necessary to give some specificity to the term “light waves.”

Response Message:

First Revision No. 12-NFPA 921-2015 [Section No. 3.3.149]

3.3.160 Scientific Method.

The systematic pursuit of knowledge involving the recognition and definition of a problem; the collection of data through observation and experimentation; analysis of the data; the formulation, evaluation and testing of ~~a~~ ~~hypothesis~~ hypotheses ; and, ~~when~~ where possible, the selection of a final hypothesis.

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Committee Statement

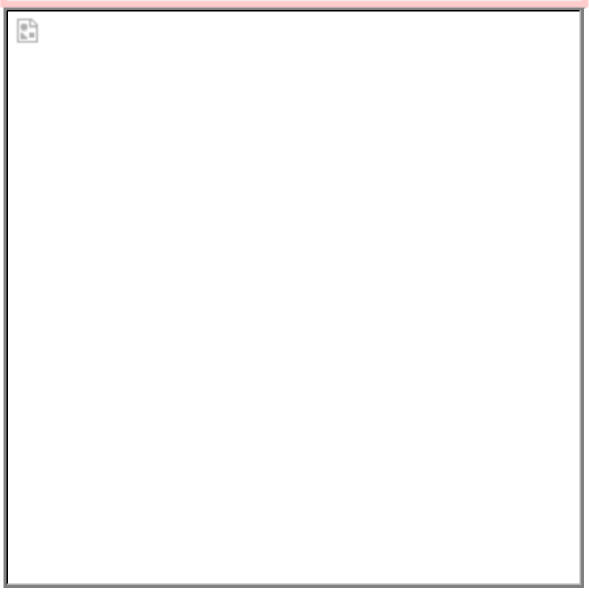
Committee Statement: Multiple hypotheses can be considered.
Response Message:

Public Input No. 320-NFPA 921-2015 [Section No. 3.3.149]

First Revision No. 13-NFPA 921-2015 [Section No. 4.3 [Excluding any Sub-Sections]]

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 4.3.1 through 4.3.10 ~~4.3.9~~ .

Figure 4.3 Use of the Scientific Method.



Supplemental Information

File Name	Description
Staff_only_FR_13_Figure_4.3.docx	Changes to Figure 4.3

Submitter Information Verification

Submitter Full Name: Michael Wixted

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Committee Statement

Committee Statement: Figure 4.3 is being modified to switch develop & test “hypothesis” to “hypotheses”.

Response Message:

Public Input No. 315-NFPA 921-2015 [Section No. 4.3 [Excluding any Sub-Sections]]

Public Input No. 87-NFPA 921-2014 [Section No. 4.3 [Excluding any Sub-Sections]]

First Revision No. 14-NFPA 921-2015 [Section No. 4.3.6 [Excluding any Sub-Sections]]

The investigator does not have a valid or reliable conclusion unless the hypothesis can stand the test of careful and serious challenge. Testing of the hypothesis is done by the principle of deductive reasoning, in which the investigator compares the hypothesis to all known facts as well as the body of scientific knowledge associated with the phenomena relevant to the specific incident. Testing of hypothesis should be designed to disprove, or refute, the hypothesis. This may also be referred to as falsification of the hypothesis. Working to disprove a hypothesis is an attempt to find all the data or reasons why the hypothesis is not supported or not true, rather than simply finding and relying on data that support the hypothesis or why the hypothesis is true. This method of testing the hypothesis can prevent "confirmation bias," which can occur when the hypothesis or conclusion relies only on supporting data *(see 4.3.10)*. A hypothesis can be tested physically by conducting experiments, analytically by applying accepted scientific principles, or by referring to scientific research. When relying on the research of others, the investigator or analyst must ensure that the conditions, circumstances, and variables of the research and those of the hypothesis are sufficiently similar. Whenever the investigator relies on research as a means of hypothesis testing, references to the research relied upon should be acknowledged and cited. If the hypothesis is refuted or not supported, it should be discarded and alternate hypotheses should be developed and tested. This may require the collection of new data or the reanalysis of existing data. The testing process needs to be continued until all feasible hypotheses have been tested and one is determined to be uniquely consistent with the facts and with the principles of science. If no hypothesis can withstand an examination by deductive reasoning, the issue should be considered undetermined.

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Committee Statement

Committee Statement: This addition adds continuity to other sections that promote "disproving the hypothesis", but this addition also provides additional guidance on how testing a hypothesis is accomplished which is not found in other sections.

Response Message:

Public Input No. 137-NFPA 921-2014 [Section No. 4.3.6 [Excluding any Sub-Sections]]

First Revision No. 16-NFPA 921-2015 [New Section after 4.3.6.1]

4.3.7 Select Final Hypothesis.

The final step in applying the scientific method is to select the final hypothesis. Once the hypothesis has been tested, the investigator should review the entire process to ensure that all credible data are accounted for and all feasible alternate hypotheses have been considered and eliminated. When using the scientific method, the failure to consider alternate hypotheses is a serious error. A critical question to be answered is, "Are there any other hypotheses that are consistent with the data?" The investigator should document the facts that support the final hypothesis to the exclusion of all other reasonable hypotheses.

Submitter Information Verification

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Committee Statement

Committee Statement: All of the steps of the Scientific Method are addressed in the methodology chapter with the exception of "Select Final Hypothesis". This new section completes the discussion. The wording of this paragraph is very similar to the wording found in the origin and cause chapters.

Response Message:

Public Input No. 148-NFPA 921-2014 [New Section after 4.3.6.1]

First Revision No. 15-NFPA 921-2015 [Section No. 4.3.7]

4.3.8 Avoid Presumption.

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

Submitter Information Verification

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Committee Statement

Committee Statement: This is an editorial correction.
Response Message:

Public Input No. 138-NFPA 921-2014 [Section No. 4.3.7]

First Revision No. 17-NFPA 921-2015 [Section No. 4.3.9]

4.3.10* Confirmation Bias.

Different hypotheses may be compatible with the same data. When using the scientific method, testing of hypotheses should be designed to disprove ~~the~~ a hypothesis (i.e., falsification of the hypothesis), rather than relying only on confirming data that support the hypothesis . Confirmation bias occurs when the investigator ~~instead tries to prove the hypothesis. This can result in~~ relies exclusively on data that supports the hypothesis and fails to look for, ignores, or dismisses contradictory or nonsupporting data. The same data may support alternate and even opposing hypotheses. The failure to consider alternate or opposing hypotheses, or prematurely discounting seemingly contradictory data without ~~an appropriate assessment~~ appropriate analysis and testing can result in incorrect conclusions . A hypothesis can be said to be valid only when rigorous testing has failed to disprove the hypothesis. Disproving the hypothesis is a process in which all the evidence is compared against the proffered hypothesis in an effort to find why the hypothesis is not true.

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Committee Statement

Committee Statement: This change clarifies the concept of falsification.

Response Message:

Public Input No. 176-NFPA 921-2014 [Section No. 4.3.9]

First Revision No. 18-NFPA 921-2015 [Section No. 5.1.1]

5.1 Introduction.

The fire investigator should have an understanding of ignition and combustion principles and should be able to use them to help in the identification and interpretation of evidence at the fire scene and in the development and testing of hypotheses regarding the origin and cause of the fire. The body of knowledge associated with combustion and fire could easily fill several textbooks. The discussion presented in this chapter should be considered introductory. *(See Annex A and Annex C for additional information.)*

5.1.1* ~~General~~ Fire and Energy .

~~The fire investigator should have an understanding of ignition and combustion principles and should be able to use them to help in the identification and interpretation of evidence at the fire scene and in the development and testing of hypotheses regarding the origin and cause of the fire. The body of knowledge associated with combustion and fire could easily fill several textbooks. The discussion presented in this chapter should be considered introductory. The user of this guide is urged to consult the reference material listed in Annex A and Annex C for additional details.~~ Fire is a rapid oxidation process, which is an exothermic chemical reaction, resulting in the release of heat and light energy in varying intensities. It is important that the fire investigator understands the basic concepts of energy, power, and radiant heat flux, and how the units of measurement for each are used to describe the behavior of fire.

5.1.2 Energy.

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). A joule is the heat produced where one ampere is passed through a resistance of one ohm for one second, or it is the work required to move over a distance of one meter against a force of one newton. A calorie is the amount of energy required to raise the temperature of 1 g of water by 1°C (e.g., from 14°C to 15°C); a calorie is equal to 4.184 J. A Btu is the quantity of heat required to raise the temperature of 1 lb of water 1°F at a pressure of 1 atmosphere and temperature of 60°F; a British thermal unit is equal to 1055 J, and 252.15 cal.

5.1.3 Power.

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).

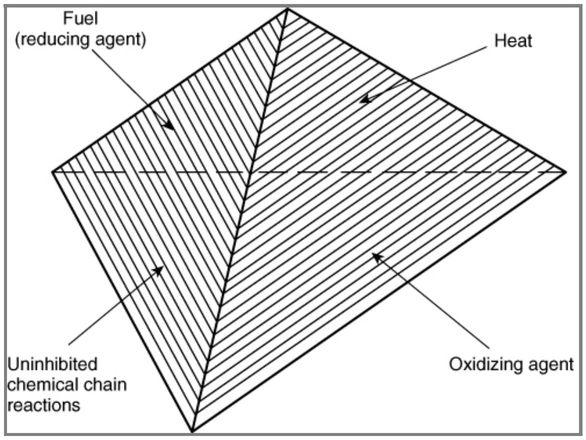
5.1.4 Heat Flux.

Heat flux is a term that describes the amount of power per unit area. A kilowatt spread over 1 m^2 is approximately equal to the radiant heat flux outdoors on a sunny day. If that same kilowatt is concentrated using a magnifying glass and only spread over .05 m^2 (500 cm^2), there may be sufficient energy transferred to that area to cause ignition of combustibles. Heat flux is measured in kW/m^2 or W/cm^2 .

5.1.5 Fire Tetrahedron.

The combustion reaction can be characterized by four components: the fuel, the oxidizing agent, the heat, and the uninhibited chemical chain reaction. These four components have been classically symbolized by a four-sided solid geometric form called a tetrahedron *(see Figure 5.1.5)*. Fires can be prevented or suppressed by controlling or removing one or more of the sides of the tetrahedron.

Figure 5.1.5 Fire Tetrahedron.



5.1.5.1 Fuel.

A fuel is any substance that can undergo combustion. The majority of fuels encountered are organic, which simply means that they are carbon-based and may contain other elements such as hydrogen, oxygen, and nitrogen in varying ratios. Examples of organic fuels include wood, plastics, gasoline, alcohol, and natural gas. Inorganic fuels contain no carbon and include combustible metals, such as magnesium or sodium. All matter can exist in one of three states: solid, liquid, or gas. The state of a given material depends on the temperature and pressure and can change as conditions vary. If cold enough, carbon dioxide, for example, can exist as a solid (dry ice). The normal state of a material is that which exists at NTP (normal temperature and pressure) conditions: 20°C (68°F) temperature, and a pressure of 101.6 kPa (14.7 psi), or 1 atmosphere at sea level.

5.1.5.1.1

Combustion of liquid fuels and most solid fuels takes place above the fuel surface in a region of vapors created by heating the fuel surface. The heat can come from the ambient conditions, from the presence of an ignition source, or from exposure to an existing fire. The application of heat causes vapors or pyrolysis products to be released into the atmosphere, where they can burn if in the proper mixture with an oxidizer and if a competent ignition source is present or if the fuel's autoignition temperature is reached. Ignition is discussed in Section 5.7.

5.1.5.1.2

Gaseous fuels do not require vaporization or pyrolysis before combustion can occur. Only the proper mixture with an oxidizer and an ignition source are needed.

5.1.5.1.3

For the purposes of the following discussion, the term *fuel* is used to describe vapors and gases rather than solids.

5.1.5.2 Oxidizing Agent.

In most fire situations, the oxidizing agent is the oxygen in the earth's atmosphere. Fire can occur in the absence of atmospheric oxygen, when fuels are mixed with chemical oxidizers. Many chemical oxidizers contain readily released oxygen. Ammonium nitrate fertilizer (NH_4NO_3), potassium nitrate (KNO_3), and hydrogen peroxide (H_2O_2) are examples.

5.1.5.2.1

Certain gases can form flammable mixtures in atmospheres other than air or oxygen. One example is a mixture of hydrogen and chlorine gas.

5.1.5.2.2

Every fuel–air mixture has an optimum ratio at which point the combustion will be most efficient. This ratio occurs at or near the mixture known by chemists as the stoichiometric ratio. When the amount of air is in balance with the amount of fuel (i.e., after burning there is neither unused fuel nor unused air), the burning is referred to as stoichiometric. This condition rarely occurs in fires except in certain types of gas fires. *(See 23.8.2.1.)*

5.1.5.3 Heat.

The heat component of the tetrahedron represents heat energy above the minimum level necessary to release fuel vapors and cause ignition. Heat is commonly defined in terms of intensity or heating rate (kilowatts) or as the total heat energy received over time (kilojoules). In a fire, heat produces fuel vapors, causes ignition, and promotes fire growth and flame spread by maintaining a continuous cycle of fuel production and ignition.

5.1.5.4 Uninhibited Chemical Chain Reaction.

Combustion is a complex set of chemical reactions that results in the rapid oxidation of a fuel, producing heat, light, and a variety of chemical by-products. Slow oxidation, such as rust or the yellowing of newspaper, produces heat so slowly that combustion does not occur. Self-sustained combustion occurs when sufficient excess heat from the exothermic reaction radiates back to the fuel to produce vapors and cause ignition in the absence of the original ignition source. For a detailed discussion of ignition, see Section 5.7.

Submitter Information Verification

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Committee Statement

Committee Statement: NFPA 1033 requires that fire investigators understand fire dynamics, but NFPA 921 does not address the basic concepts of energy power and heat flux in any organized fashion. The addition of four paragraphs at the outset of the chapter on Basic Fire Science provides the necessary information.

Response Message:

First Revision No. 137-NFPA 921-2015 [Section No. 5.2.3.4]

5.2.3.4*

Diffusion flames can only occur for certain concentrations of the mixture components. The lowest oxygen concentration in nitrogen is termed the limiting oxygen index (LOI). For most fuel vapors, the LOI is in the range of 10 percent to 14 percent by volume at ordinary temperatures (Beyler 2002). Similarly, ~~the~~ a fuel gas stream can be diluted with nitrogen or other inert gas to the extent where burning is no longer possible. For example, methane diluted with nitrogen to below 14 percent methane will not burn with air at normal temperatures. An underventilated compartment fire may behave like a large diffusion flame. In a ventilation-controlled compartment fire, oxygen concentrations can drop to near zero at locations away from sources of ventilation. This will limit flaming combustion within the compartment.

Submitter Information Verification

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Committee Statement

Committee Statement: The committee believes that the additional material clarifies the scientific information within the document.
Response Message:

First Revision No. 138-NFPA 921-2015 [Section No. 5.3.2]

5.3.2

~~When~~ Where less air is available for combustion, as in ventilation-controlled fires *(see 5.10.2.8)* , the production of carbon monoxide increases as does the production of soot and unburned fuels.

Submitter Information Verification

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Committee Statement

Committee Statement: The committee believes that the additional material clarifies the scientific information within the document.
Response Message:

First Revision No. 139-NFPA 921-2015 [Section No. 5.3.9]

5.3.9

Smoke production rates are generally less in the early phase of a fire but increase greatly with the onset of flashover, if flashover occurs. At the beginning of a fire there is an abundance of oxygen, but after flashover the fire usually becomes significantly underventilated. This can be demonstrated by putting a glass over a candle and observing increased smoke production due to reducing oxygen in the volume surrounding the flame.

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Response Message:

First Revision No. 23-NFPA 921-2015 [Section No. 5.5.5.3.4]

5.5.5.3.4*

Most fire science calculations involving temperature require that ~~absolute degrees~~ specific units of temperature be used — typically Kelvins or degrees Celsius. It is important to understand the particular equation and know what units are required to ensure accurate results .

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Committee Statement

Committee Statement: Adding the revised language clarifies this section and prompts the user to understand the particular equation and utilize the right scale to ensure accurate results.

Response Message:

Public Input No. 264-NFPA 921-2015 [Section No. 5.5.5.3.4]

First Revision No. 24-NFPA 921-2015 [Section No. 5.6.3.1]

5.6.3.1 General.

Total fuel load in the room has no bearing on the rate of growth of a given fire in its ~~pre-flashover~~ preflashover phase. During this period of development, the rate of fire growth is determined by the heat release rate (HRR) from the burning of individual fuel arrays. The HRR describes how the available energy in a given material or group of materials is released. This quantity characterizes the power or energy release rate [watts(joules/sec) or kilowatts] of a fire and is a quantitative measure of the size of the fire. A generalized HRR curve can be characterized by an initial growth stage, a period of steady-state burning, and a decay stage as shown in Figure 5.6.3.1(a) through Figure 5.6.3.1(c). Equation 5.6.3.1 can be used to calculate the ~~heat release rate~~ HRR of a burning item. The heat of combustion is generally considered a material property and therefore a constant for a specific fuel. Values for specific fuels can generally be obtained from the literature. The mass burning rate of a fuel is dependent ~~upon~~ on several factors, including surface area, fuel type, and fuel configuration. Steady-state burning rate values for many fuels have been studied and are available in the sources following Table 5.6.3.1. The largest value of the HRR measured is defined as the ~~*peak heat release rate*~~ peak HRR. Representative peak HRRs for a number of fuel items are listed in Table 5.6.3.1. These values should only be considered as representative values for comparative purposes. Fuel items with the same function (e.g., sofas) can have significantly different HRRs. The actual peak ~~heat release rate~~ HRR for a particular fuel item is best determined by test. The ~~heat release rate~~ HRR during the growth phase generally increases as a result of increasing flame spread rates over the fuel package. The peak or steady period of heat release is characterized by full involvement of the fuel surface of the package in flames. The decay phase reflects the reduction in remaining fuel and fuel area available to burn or some other interruption of the uninhibited chain reaction, including consumption of available oxygen or suppression activities. The onset, duration, and severity of these stages depend on a variety of factors, including the incident heat flux to the burning item, the chemical and physical properties of the fuel, the surface area of the fuel, the substrate on which the fuel is burning, and whether or not it is burning in an enclosed environment.

~~$\dot{Q} = \dot{m}\Delta H_c$~~ $$\dot{Q} = \dot{m}'' A \Delta H_c \qquad \textbf{[5.6.3.1]}$$

where:

$\dot{Q}$ = heat release rate (kW)

~~$\dot{m}$ = mass burning rate of the fuel (kg/s)~~

$\dot{m}''$ = mass loss per unit area per second (kg/m^2 • s)

A = area in m^2

ΔH_c = heat of the combustion of the fuel (kJ/kg)

Figure 5.6.3.1(a) Idealized HRR Curve for a ~~Fuel Controlled~~ Fuel-Controlled Fire.

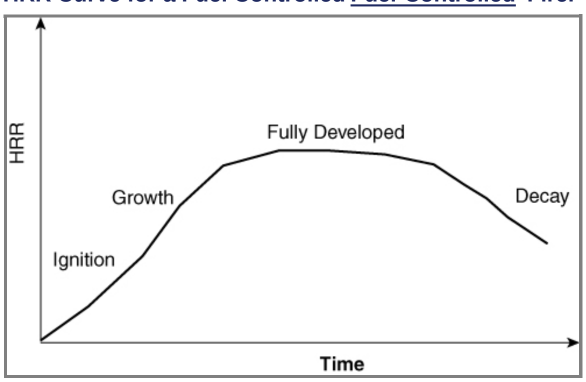

Figure 5.6.3.1(b) Idealized HRR Curve for a ~~Ventilation Controlled~~ Ventilation-Controlled Fire.

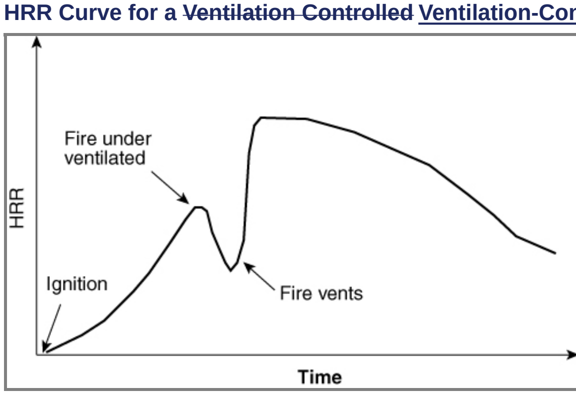

Figure 5.6.3.1(c) Actual Temperature Measurements from a Test Fire That Became Underventilated and Then Became Ventilated by the Opening of the Door.

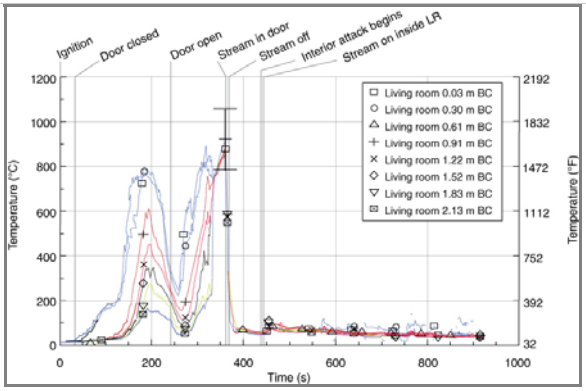

Table 5.6.3.1 Representative Peak ~~Heat Release Rates~~ HRRs (Unconfined Burning)

Fuel	Weight		Peak HRR (kW)
	kg	lb	
Wastebasket, small	0.7–1.4	1.5–3	4–50
Trash bags, 42 L (11 gal) with mixed plastic and paper trash	2.5	7.5	140–350
Cotton mattress	12–13	26–29	40–970
TV sets	31–33	69–72	120 to over 1500
Plastic trash bags/paper trash	1.2–14	2.6–31	120–350
PVC waiting room chair, metal frame	15	34	270
Cotton easy chair	18–32	39–70	290–370
Gasoline or kerosene in 0.2 m^2 (2 ft^2) pool	19	42	400
Christmas trees, dry	6–20	13–44	3000–5000
Polyurethane mattress	3–14	7–31	810–2630
Polyurethane easy chair	12–28	27–61	1350–1990
Polyurethane sofa	51	113	3120
Wardrobe, wood construction	70–121	154–267	1900–6400

Sources: Values are from the following publications:

Babrauskas, V. and Krasny, J., *Fire Behavior of Upholstered Furniture*, NBS Monograph 173 Fire Behavior of Upholstered Furniture.

Babrauskas, V., "Heat Release Rates," in *SFPE Handbook of Fire Protection Engineering*, 3rd ed., National Fire Protection Association.

Lee, B.T., *Heat Release Rate Characteristics of Some Combustible Fuel Sources in Nuclear Power Plants*, NBSIR 85-3195.

NFPA 72~~,~~ ~~*National Fire Alarm and Signaling Code*~~ .

5.6.3.1.1

Data from experiments conducted by NIST in acquired structures demonstrate the impact of ventilation on the temperatures in the structure fire. As the oxygen contained within the structure is reduced, the HRR of the fire decreases, and as a result, the gas temperatures within compartments in the structure decrease. As additional oxygen is made available to the fire due to a change in ventilation, such as the opening of a door or window, the HRR ~~release rate~~ and temperature begin to increase again. This idealized ventilation-controlled model needs to be understood as a potential fire growth curve in structure fires by both firefighters and fire investigators.

5.6.3.1.2

While the rate of fire growth in a compartment is determined by the HRR of the fuel array, the rate of growth of a particular fuel item and its maximum HRR is a function of its properties, including the area of the fuel, the rate of mass loss, and the effective heat of combustion. The orientation of a particular fuel item may also affect the rate at which it reaches its maximum HRR. For example, a mattress in a horizontal configuration typically takes longer to reach maximum HRR than a similar mattress in a vertical configuration.

Supplemental Information

File Name	Description
Staff_only_FR_24_Eq_5.6.3.1.docx	Equation 5.6.3.1 and Committee Statement.

Submitter Information Verification

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Committee Statement

Committee Statement: See attached committee statement.
Response Message:

Public Input No. 267-NFPA 921-2015 [Section No. 5.6.3.1]

First Revision No. 140-NFPA 921-2015 [Section No. 5.10.2.5]

5.10.2.5

In the early stage of burning, there is sufficient air to burn all of the materials being pyrolyzed. This is referred to as *fuel-controlled burning*. As the burning progresses, the availability of air may continue and the fire may have sufficient oxygen even as it grows. Normally, this would be a compartment that had a large door or window opening. In such cases, the gases collected at the upper portion of the room~~, while hot,~~ will contain significant oxygen and relatively small amounts of unburned fuel.

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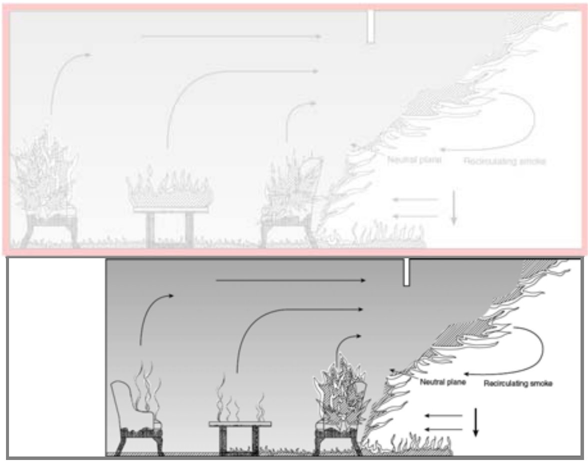
Response Message:

First Revision No. 141-NFPA 921-2015 [Sections 5.10.2.7, 5.10.2.8]

5.10.2.7

If the air flow into the compartment is not sufficient to burn all of the combustibles being pyrolyzed by the fire, the fire will shift from fuel controlled (i.e., where the heat release rate of the fire depends on the amount of fuel involved) to ventilation controlled (i.e., where all the fuel is on fire, and the heat release rate is controlled by the amount of oxygen available). In a ventilation-controlled fire, the hot gas layer will contain high levels of unburned pyrolysis products and carbon monoxide, and very low levels of oxygen . (*See Figure 5.10.2.7*.)

Figure 5.10.2.7 Postflashover or Full Room Involvement in a Typical Compartment Fire. Although pyrolysis can continue throughout the compartment, flaming combustion will only occur where there is sufficient oxygen present. Depending on the momentum of the entraining air, flaming combustion may occur within the ventilation stream at various depths into the compartment.



5.10.2.8

During postflashover burning, the position of the ~~bottom of the ceiling~~ bottom-of-the-ceiling layer and the existence and size of flaming on or associated with target fuels within the layer can vary between the conditions shown in Figure 5.10.2.6 and Figure 5.10.2.7. While the burning of floors or floor coverings is common, such burning may not always extend under target fuels or other shielding surfaces. This fully developed fire stage is typically ventilation-controlled burning.

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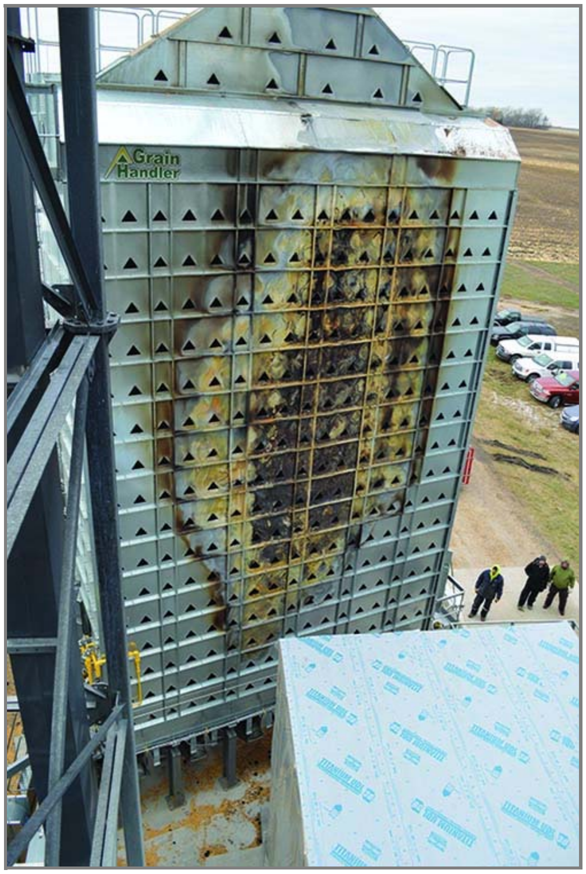
Committee Statement: The committee believes that the additional material clarifies the scientific information within the document.
Response Message:

First Revision No. 128-NFPA 921-2015 [Section No. 6.2.6.3]

6.2.6.3

~~When~~ Where uncoated iron or steel is oxidized in a fire, the surface first acquires a blue-gray dullness. At elevated temperatures, iron may also combine with oxygen to form black oxides. Oxidation can produce thick layers of oxide that can flake off. After the fire, if the metal has been wet, the usual rust-colored oxide may appear. *(See Figure 6.2.6.3 .)*

Figure 6.2.6.3 Heat-Induced Color Change to Metal on Grain Dryer.



Supplemental Information

File Name	Description
Staff_only_FR_128_Fig_6.2.6.3.JPG	1. New figure 6.2.6.3.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: Inclusion of color image as an example.

Response Message:

First Revision No. 25-NFPA 921-2015 [Section No. 6.2.10.3]

6.2.10.3* Enhanced Soot Deposition ~~(~~ , or Acoustic Soot Agglomeration ~~)~~ , on Smoke Alarms.

In many cases, the nature of soot deposition on certain surfaces of typical single- or ~~multiple-station~~ multistation smoke alarms can show that the smoke alarm sounded or did not sound during a fire. Enhanced soot deposition ~~(~~ , or acoustic soot agglomeration ~~)~~ , is a phenomenon whereby the soot particulate in smoke forms identifiable patterns on such surfaces of the smoke alarm as the internal and external surfaces of the smoke alarm cover near the edges of the "horn" ~~(~~ or sound ~~)~~ outlet(s), the edges of ~~and~~ the "horn" or sound outlet(s) of the interior "horn" enclosures if present, and surfaces of the "horn" disks themselves. *[See Figure 6.2.10.3(a) through Figure 6.2.10.3(d).]*

Figure 6.2.10.3(a) An Unpowered ~~(Non-Functioning)~~ , Nonfunctioning Smoke Alarm After Exposure to a Sooty Atmosphere.

Figure 6.2.10.3(b) ~~Close-Up~~ Close-up of the External "Horn" ~~(~~ or Sound ~~)~~ Outlet of the Unpowered Smoke Alarm Displayed in Figure 6.2.10.3(a) After Exposure to a Sooty Atmosphere, Showing No Enhanced Soot Deposition.

Figure 6.2.10.3(c) A Duplicate Powered ~~(~~ , Functioning ~~)~~ Smoke Alarm After Exposure to the Same Sooty Atmosphere as the Smoke Alarm in Figure 6.2.10.3(a) and Figure 6.2.10.3(b), Displaying Typical Enhanced Soot Deposition.

Figure 6.2.10.3(d) ~~Close-Up~~ Close-up of the External "Horn" ~~(~~ or Sound~~)~~ Outlet of the Powered Smoke Alarm Displayed in Figure 6.2.10.3(c) After Exposure to a Sooty Atmosphere, Showing Enhanced Soot Deposition.

6.2.10.3.1

Scene investigators should be cognizant of the importance of smoke alarms that may bear physical evidence of alarm activation and consider more detailed documentation, examination, and collection of such evidence.

6.2.10.3.2

Enhanced soot deposition, or acoustic agglomeration, evidence can be delicate and easily disturbed or wiped away by careless handling or evidence packaging of the smoke alarm(s) in question. Care should be taken not to disturb any suspected soot deposits.

6.2.10.3.3

Evidence of enhanced soot deposition, or acoustic agglomeration, on smoke alarms can be subtle and sometimes difficult to identify. Examination may require microscopic magnification.

6.2.10.3.4

Smoke alarms should be taken into evidence ~~when~~ where smoke alarm performance may be an issue. The alarm should be collected as evidence after being photographed in place and should not be altered by applying power, removing or inserting batteries, or pushing the test button. Alarms still on the wall or ceiling should be secured intact with mounting hardware, electrical boxes, and wired connections. Removing a section of wall material with the alarm may be needed to preserve the condition of the alarm and all electrical power connections.

6.2.10.3.5

Investigators should keep in mind that enhanced soot deposition, or acoustic smoke agglomeration deposits, are persistent. The presence of acoustic smoke agglomeration deposits may not necessarily indicate when the agglomeration occurred~~,~~ without additional data.

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Committee Statement

Committee Statement: These are editorial changes.

Response Message:

Public Input No. 289-NFPA 921-2015 [Section No. 6.2.10.3]

Public Input No. 287-NFPA 921-2015 [Section No. 6.2.10.3.2]

First Revision No. 26-NFPA 921-2015 [Section No. 6.2.11 [Excluding any Sub-Sections]]

A clean burn is a distinct and visible fire effect generally apparent on ~~non-combustible~~ noncombustible surfaces after combustible layer(s) ~~(~~ such as soot, paint, and paper~~)~~ have been burned away. The effect may also appear where soot has failed to deposit because of high surface temperatures. A fire exposure to the surface can produce a clean area adjacent to areas darkened by products of combustion, as shown in Figure 6.2.11(a) and Figure 6.2.11(b). Clean burn patterns produced by burning away of soot can be produced by direct flame contact or intense radiated heat. Smoke deposits on surfaces are subject to oxidation. The dark char of the paper surface of gypsum wallboard, soot deposits, and paint can be oxidized by continued flame exposure. The carbon will be oxidized to gases and disappear from the surface. *[See Figure 6.2.11(c).]*

Figure 6.2.11(a) Clean Burn on Wall Surface.

Figure 6.2.11(b) Clean Burn Pattern on Wallboard Behind Sofa.

Figure 6.2.11(c) Early Formation of Clean Burn Pattern on Left Wall.

Submitter Information Verification

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Committee Statement

Committee Statement: Changes are consistent with the definition in 3.3.30.

Response Message:

Public Input No. 268-NFPA 921-2015 [Section No. 6.2.11 [Excluding any Sub-Sections]]

First Revision No. 142-NFPA 921-2015 [Section No. 6.2.11.1]

6.2.11.1

Although they can be indicative of intense heating in an area, clean burn areas by themselves do not necessarily indicate areas of origin, though such patterns should be carefully examined. Clean burning that results from ventilation will usually occur after the fire has become ~~ventilation-controlled~~ ventilation controlled . Such late-developing patterns may be misleading in origin determination. The lines of demarcation between the clean-burned and darkened areas may be used by the investigator to determine direction of fire spread or differences in intensity or time of burning. Determinations as to the direction of fire spread based on such patterns should be accompanied by a determination as to the likely mode of the pattern generation. *(See Figure 6.2.11.1 .)*

Figure 6.2.11.1 Clean Burn Above the Origin of a Test Fire.

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Committee Statement

Committee Statement: The committee believes that the additional material clarifies the scientific information within the document.

Response Message:

First Revision No. 27-NFPA 921-2015 [Section No. 6.3.1.2 [Excluding any Sub-Sections]]

Lines or areas of demarcation are the borders defining the differences in certain heat and smoke effects of the fire on various materials. They appear between the affected area and adjacent, less-affected areas. *(See Figure 6.3.1.2 .)*

Figure 6.3.1.2 Line of Demarcation.

Supplemental Information

File Name	Description
Staff_only_FR_27_Fig_6.3.1.2.JPG	New jpeg image.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: The added image illustrates lines of demarcation.
Response Message:
Public Input No. 237-NFPA 921-2015 [Section No. 6.3.1.2 [Excluding any Sub-Sections]]

First Revision No. 129-NFPA 921-2015 [Section No. 6.3.2.5]

6.3.2.5 Suppression-Generated Patterns.

Water or other agents used for fire suppression are capable of producing or altering patterns. Hose streams are capable of altering the spread of the fire and creating fire damage in places where the fire would not move in the absence of the hose stream. Additionally, fire department ventilation operations can influence fire patterns. Some fire departments use positive pressure ventilation (PPV) fans that can create patterns that may be difficult to interpret, particularly if the investigator is unaware of PPV use. The history of suppression-generated patterns can only be understood through communication with the responding fire suppression personnel. *[See Figure 6.3.2.5(a) , Figure 6.3.2.5(b) ~~Figure 6.3.2.5(b)Figure 6.3.2.5(a)~~ , and Figure 6.3.2.5(c) ~~Figure 6.3.2.5(c)Figure 6.3.2.5(b)~~ .]*

Figure 6.3.2.5(a) Suppression-Generated Patterns with Hose Stream.

Figure 6.3.2.5(b) Pattern on Ceiling Created by Hose Stream.

Figure 6.3.2.5(c) Pattern on Wall Created by Hose Stream.

Supplemental Information

File Name	Description
Staff_only_FR_129_Fig_6.3.2.5_a_.jpg	1. New Figure 6.3.2.5(a).

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: Inclusion of additional color image as an example.
Response Message:

First Revision No. 28-NFPA 921-2015 [Section No. 6.3.3.2.5]

6.3.3.2.5

Holes in floors may be caused by glowing combustion, radiation, ~~or an~~ ignitible liquid, or effects of ventilation . The surface below a liquid remains cool, ~~(~~ or at least below the boiling point of the liquid ~~)~~ , until the liquid is consumed. Holes in the floor from burning ignitible liquids may result when the ignitible liquid has soaked into the floor or accumulated below the floor level. Evidence other than the hole or its shape is necessary to confirm the cause of a given pattern.

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Submittal Date: Thu May 14 10:48:51 EDT 2015

Committee Statement

Committee Statement: The committee believes the addition of the term ventilation to this section addresses an important concept related to holes in floors.

Response Message:

Public Input No. 265-NFPA 921-2015 [Section No. 6.3.3.2.5]

First Revision No. 29-NFPA 921-2015 [New Section after 6.3.5.1]

6.3.5.2*

Research has shown that the burning of ignitible liquids is rarely the sole cause of floor penetrations.

Supplemental Information

File Name	Description
FR_29_A.6.3.5.2.docx	New annex A.6.3.5.2

Submitter Information Verification

Submitter Full Name: Michael Wixted

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Submittal Date: Thu May 14 10:53:57 EDT 2015

Committee Statement

Committee Statement: The committee believes that some research has shown that the burning of ignitible liquids is rarely the sole cause of floor penetrations.

Response Message:

Public Input No. 130-NFPA 921-2014 [New Section after 6.3.5.2]

A.6.3.5.2 For more information see Mealy, Benfer and Gottuk, *Fire Dynamics and Forensic Analysis of Liquid Fuel Fires*, NCJ 238704, 2011, available at NCJRS.gov.

First Revision No. 30-NFPA 921-2015 [Section No. 6.3.7.8.3]

6.3.7.8.3

~~When~~ Where overall fire damage is limited and small, or isolated irregular patterns are found, further examination should be conducted for supporting evidence of ignitible liquids. *[See Figure 6.3.7.8.3(a) and Figure 6.3.7.8.3(b).]* Even in these cases, radiant heating may cause the production of patterns on some surfaces that can be misinterpreted as liquid burn patterns. *[See Figure 6.3.7.8.3(c) through Figure 6.3.7.8.3(f).]*

Figure 6.3.7.8.3(a) Irregular Burn Patterns on a Floor of a Room Burned in a Test Fire in Which No Ignitible Liquids Were Used.

Figure 6.3.7.8.3(b) Irregularly Shaped Pattern on Carpet Resulting from ~~Poured~~ the Burning of an Ignitible Liquid~~; Burned Match Can be Seen at Lower Left~~ .

Figure 6.3.7.8.3(c) "Pool-Shaped" Burn Pattern Produced by a Cardboard Box Burning on an Oak Parquet Floor.

Figure 6.3.7.8.3(d) Irregular Pattern on Carpet.

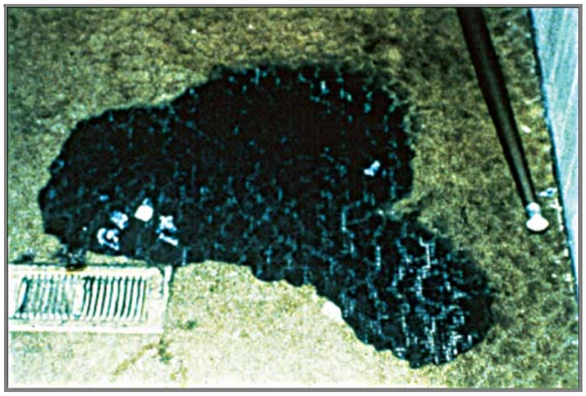

Figure 6.3.7.8.3(e) Test Burn on Vinyl Tiles.

Figure 6.3.7.8.3(f) Irregular Pattern Created from Test Burn of Newspapers on Vinyl Tiles.

Supplemental Information

File Name	Description
Staff_only_FR_30_Fig_6.3.7.8.3b.jpg	Jpeg file of new image.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Committee Statement

Committee Statement: The committee believes that the color image better illustrates the text.
Response Message:
Public Input No. 225-NFPA 921-2014 [Section No. 6.3.7.8.3]

First Revision No. 31-NFPA 921-2015 [Section No. 6.3.7.12]

6.3.7.12 Saddle Burns.

Saddle burns are distinctive U- or saddle-shaped patterns that are sometimes found on the top edges of floor joists. They are caused by fire burning downward through the floor above the affected joist. Saddle burns display deep charring, and the fire patterns are highly localized and gently curved. They also may be created by radiant heat from a burning material in close proximity to the floor, including materials that may melt and burn on the floor (e.g., polyurethane foam). Ventilation caused by floor openings may also contribute to the development of these patterns, shown in Figure 6.3.7.12.

Figure 6.3.7.12 Saddle Burn in a Floor Joist.

Supplemental Information

File Name	Description
Staff_only_FR_31_Fig_6.3.7.8.12.jpg	New jpeg image.

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Committee Statement

Committee Statement: The committee believes that the color image better illustrates the text.

Response Message:

Public Input No. 226-NFPA 921-2014 [Section No. 6.3.7.12]
Public Input No. 218-NFPA 921-2014 [Section No. 6.3.7.12]

First Revision No. 143-NFPA 921-2015 [Section No. 6.4.1.2]

6.4.1.2.1

Every fire pattern in a fully involved compartment should be analyzed to determine whether it could have resulted from ventilation. Patterns that can be accounted for in terms of ventilation may provide little insight into the behavior of the fire in its early stages.

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Committee Statement

Committee Statement: The committee believes that the additional material clarifies the scientific information within the document.
Response Message:

First Revision No. 32-NFPA 921-2015 [Section No. 7.8.8]

7.8.8

The identification~~ of~~ , handling, storage, and transfer of evidence may be critical in ~~allowing~~ providing all interested parties the ~~opportunities~~ opportunity to evaluate the evidence. ~~Whenever~~ Where possible, all interested parties ~~shall~~ should be notified of the loss and ~~invited to~~ given the ~~site~~ opportunity to examine the evidence in place. If the collection of evidence is deemed necessary for further analysis~~ of the evidence or to provide other parties with their own opportunity to collect the evidence~~ , care should be taken to minimize~~ the~~ destruction ~~and alternation~~ or alteration of the evidence during the collection and handling processes. ~~The destruction~~ Destruction or ~~alternation~~ alteration of the evidence without~~ all parties~~ consent~~ and/or agreement and/or presence can be deemed spoliation.~~ , agreement, or presence of other known interested parties could result in a claim of evidence spoliation. *(See also 12.3.5 .)*

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City:

State:

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Chapter 8 Active Fire Protection Systems

8.1* Introduction.

This chapter provides a basic understanding of active fire protection systems, which includes general information, key components, operational and installation parameters, data gathering, and analysis. Passive fire protection systems are addressed in Chapter 7. It is important to have a basic knowledge of fire protection systems present and their performance during an incident ~~in order~~ to understand the role of the system and ~~potential~~ its impact on the fire incident.

8.1.1

This chapter provides a description of the most commonly found systems installed in buildings. Fire alarm systems, including detection and notification appliances, water-based systems, and fire suppression systems are discussed.

8.1.2*

This chapter is an introduction to the types of systems and how they should be documented and addressed during the fire investigation. A plethora of resources exist that describe these systems in much greater detail. The user of this guide is urged to consult the reference material listed in Annex A for more information.

8.1.3

The performance of the fire protection systems may be relevant to the development or testing of hypotheses associated with the origin, cause, or spread of a fire, and as such the system must be preserved and documented.

8.1.4

The documentation and analysis of active fire protection systems often needs the technical assistance of engineers or technical specialists. The movement, manipulation, energizing, and de-energizing of system components may result in the destruction of critical data. The loss of this data may hinder the analysis and formulation of origin and cause hypotheses and might be considered spoliation of evidence. Even if the scope of an investigator's assignment does not include the analysis of the fire protection systems, the documentation and analysis of those systems may be important to other interested parties, so the preservation of those systems is critical.

8.2 Documentation of Fire Protection Systems.

8.2.1 Design Documentation.

Design documentation regarding the particular fire protection system or component of interest to the investigator should be obtained. The number of design documents and the location of those documents may vary according to the specific type of system or component. Design documents are often modified from the time the project is conceived until it is built or installed. ~~Obtain~~ The investigator should obtain as many ~~of the~~ versions as possible. Design documents may be in the possession of the designer, manufacturer, certifying agency, installer, building owner or occupant, or the AHJ.

8.2.2 Permit History.

If the design and/or installation of the system or component required a permit by the AHJ, the original permit file in the possession of the AHJ should be examined by the investigator and copied if necessary. The permit file may contain design drawings, modifications demanded by the AHJ, notices of deficiencies, and inspection reports. If a permit was required by the AHJ but none was obtained, it should be noted.

8.2.3 Invoices and Contracts.

Draft contracts, final contracts, revised contracts, and invoices for services and materials should be obtained by the investigator. These documents may be in the possession of the parties to the contract, product seller, service provider, or installer.

8.2.4 Installation Documentation.

Upon completion of the project, "as built" plans may have been provided to the owner of the building. Depending upon the system, the furnishing of the "as built" drawings may be required per ~~the~~ a standard, a code, or the AHJ. It is important to compare the "as built" plans with the actual installation as they may not conform. Discrepancies between the "as built" plans and the actual installation should be noted.

8.2.5 Inspection and Maintenance Records.

Some fire protection systems are required to have periodic inspection and maintenance. Codes, standards, and the AHJ may require ~~the~~ periodic inspection and maintenance of systems and that such inspections and maintenance be documented. The inspection and maintenance documents may be found in the possession of the building owner or entity responsible for the building, the entity that serviced and/or inspected the system, and the AHJ.

8.2.6 Product Literature.

Information about the product generated by the manufacturer of the system or component part should be obtained. The literature may be in the possession of the system owner, product distributor, seller, or available directly from the manufacturer. Product literature is often available on distributor and manufacturer websites. Product literature may have changed from the time the product was purchased or installed and the date of the investigation. Even if the original literature is available to the investigator, current literature on the product should be obtained to determine if any significant changes in the product or the literature have been made by the manufacturer. These changes may include design changes that impact the investigation and warnings that were not present in the original documentation. Some products~~, in order~~ to meet the requirements of the AHJ, must be listed by a certifying agency such as Underwriters Laboratories (UL). The certifying agency will maintain a file on its testing of the product and possibly its inspection of the production facility.

8.2.7 Alarm/Activation History.

Alarm systems may be monitored, sending data~~,~~ in addition to alarm activation information~~,~~ to a central monitoring station. The alarm monitoring company should be alerted as soon as possible to preserve all data recorded on its system. Some alarm panels retain data on the panel that is not transmitted to the central monitoring station. The data ~~resident to~~ retained in the panel may be lost if the panel losses electrical power. The alarm system may have battery back-up power, but once the battery losses its charge~~,~~ the data may be lost. Care should be taken to preserve the panel and its~~ source of~~ power source . The assistance of a qualified alarm expert should be considered before the data is lost or the panel is removed or manipulated.

8.3* Fire Alarm Systems.

8.3.1 General Information.

8.3.1.1 Purpose of Systems.

A fire detection and alarm system is an important element among the fire protection features of any building. Because most fire deaths result from building fires, the use of properly specified, designed, manufactured, installed, maintained, and tested fire detection and alarm systems in buildings can help to significantly reduce the loss of life from fire. Also~~, if properly specified, designed, manufactured, installed, maintained, tested, and used, a~~ fire detection and alarm systems ~~can~~ may help limit property fire losses in buildings, regardless of occupancy.

8.3.1.2* System Components.

Fire alarm systems are classified according to the functions they are expected to perform. The basic components of each system include a system control unit; a primary, or main, power supply; a secondary, or standby, power supply; one or more initiating device circuits; one or more fire alarm notification appliance circuits; and, in some cases, off-premises monitoring.

8.3.1.3 General System Operation.

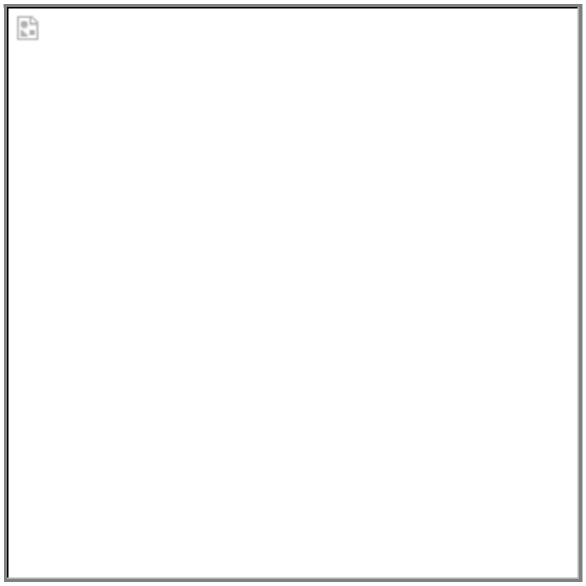
The operation of a fire alarm system begins with detection of a fire. This detection could consist of a building occupant discovering a fire and activating a manual fire alarm box (i.e., a pull station) , or activation of an automatic fire detection device. Following the detection of a fire, notification appliances alert the building's occupants, and, depending on the system design, emergency services.

8.3.2* Key Components of Systems.

8.3.2.1 Fire Alarm Control Unit (FACU).

An FACU is the component of the fire alarm system that receives signals from initiating devices, ~~(~~ such as smoke or heat detectors or manual pull stations~~)~~ , or other FACUs, and processes these signals to determine part or all of the required fire alarm system output function(s) ~~(such as an alarm signal; suppression system; or HVAC system control)~~ that should be activated, such as an alarm signal, suppression system, or HVAC system control . An FACU (i.e., a panel) is generally provided with primary and secondary power sources. Figure 8.3.2.1 shows an example of an FACU with a display panel.

Figure 8.3.2.1 FACU/LCD Display.



8.3.2.2 Power Supply.

A power supply is a source of electrical operating power, ~~including~~ which includes the circuits and terminations connecting it to the dependent system components.

8.3.2.2.1 Primary.

For fire alarm systems (~~i.e.,~~ utilizing an FACU, and including household fire alarm systems~~)~~ , primary power is typically provided by a dedicated branch circuit via commercial light and power or an engine-driven generator with trained personnel on duty. For smoke alarms ~~(i.e.,~~ devices not requiring an FACU~~)~~ , primary power can be either a branch circuit or, in certain circumstances, via battery per specific requirements in ~~the~~ standards~~,~~ such as *NFPA 72~~, National Fire Alarm Signaling Code~~* .

8.3.2.2.2 Secondary.

Household and commercial fire alarm systems are required to have a secondary power supply, typically a battery. In general, most current systems are designed for 24 hours of backup power. Many ~~AC powered~~ AC-powered smoke alarms also have battery backup power~~;~~ . ~~these devices~~ These alarms will typically function for at least 7 days on battery backup power.

8.3.2.3 Initiating Devices.

A system component that originates transmission of a change-of-state condition, such as ~~in~~ a smoke detector, manual fire alarm box, or supervisory switch.

8.3.2.3.1 Spot-Type.

A device in which the detecting element is concentrated at a particular location, such as a single point on a ceiling. A smoke alarm is an example of a spot-type device.

8.3.2.3.2 Line-Type.

A device in which detection is continuous along a path, such as heat-sensitive cable and projected-beam smoke detectors.

8.3.2.3.3 Video.

A detection system that covers a volume by automatically analyzing real-time video images to detect smoke or flame.

8.3.2.4 Smoke Detection.

8.3.2.4.1 Smoke Detectors vs. Smoke Alarms.

A *smoke detector* is part of a fire alarm system, and a *smoke alarm* is a unit that includes the detection and warning components all in one unit and does not require an FACU for power and supervision per *NFPA 72* . Some smoke detectors do include sounders; however, they ~~require connection~~ must be connected to an FACU to operate. Figure 8.3.2.4.1(a) shows an example of a smoke alarm and Figure 8.3.2.4.1(b) shows an example of a smoke detector.

Figure 8.3.2.4.1(a) Wireless Interconnectable Multiple-Station Smoke Alarm. [72 Handbook: **Figure 29.10]**

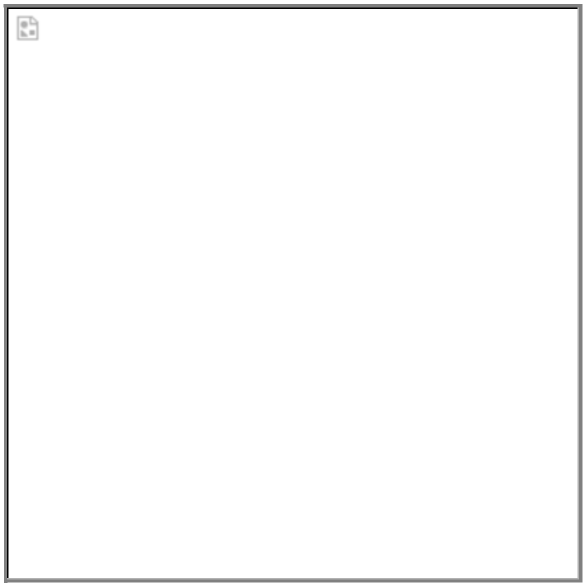
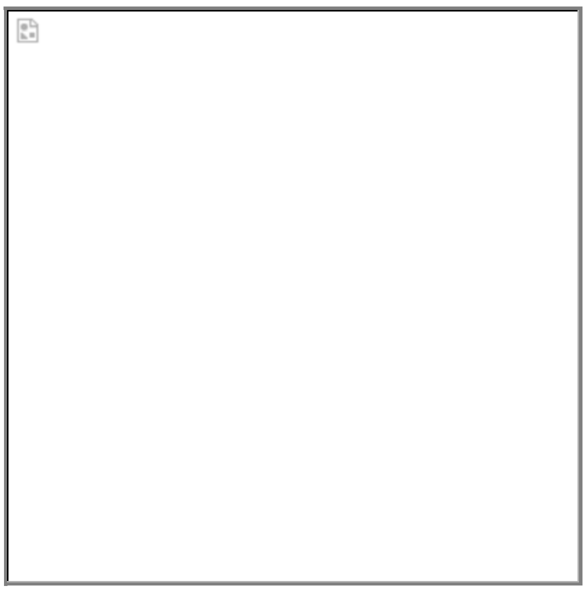


Figure 8.3.2.4.1(b) Electronic Spot-Type Smoke Detector. [72 Handbook: **Figure 3.19]**



8.3.2.4.2 Ionization.

~~The~~ *Ionization* is the principle of using a small amount of radioactive material to ionize the air between two differentially charged electrodes to sense the presence of smoke particles. Smoke particles entering the ionization volume, or chamber, decrease the conductance of the air by reducing ion mobility. The reduced conductance signal is processed and used to convey an alarm condition when it meets preset criteria. Ionization detectors are generally more sensitive to flaming fires than photoelectric detectors. The vast majority of smoke alarms in residential occupancies are ionization devices. Figure 8.3.2.4.2 shows a diagram of the principle of operation of an ionization sensor.

Figure 8.3.2.4.2 Operation of Ionization Smoke Detector. [72 Handbook: **Figure 3.35]**

8.3.2.4.3 Photoelectric.

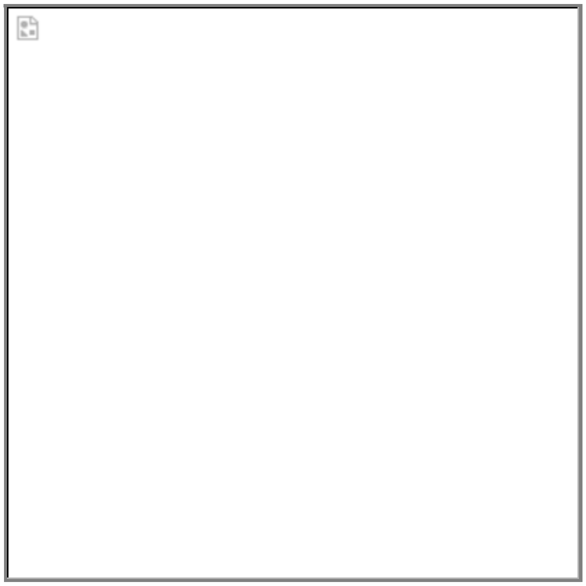
~~The~~ *Photoelectrics* is the principle of using a light source and a photosensitive sensor that is typically off-set from the path of the light source as shown in Figure 8.3.2.4.3 . ~~Typically~~ In general , photoelectric detectors ~~are devices that~~ measure ~~the scatter of light when smoke enters~~ the amount of light ~~path and scatters light~~ scattered onto the sensor when smoke enters ~~, which would otherwise be out of the path of the light source. Another type of photoelectric device measures the reduction of light normally directed onto the sensor because of smoke obscuring~~ the light path. Photoelectric detectors are generally more sensitive to smoldering fires than ionization detectors. The majority of detectors in fire alarm systems (e.g., commercial, household, and fire/security) are photoelectric devices.

Figure 8.3.2.4.3 Operation of Photoelectric Light-Scattering Smoke Detector. [72 Handbook: **Figure 3.37]**

8.3.2.4.4 ~~Air-Sampling~~ Air Sampling — ~~(~~ Aspirated~~)~~ .

Air sampling systems consist of a network of pipe or tubing with sampling holes that draws air from the protected space back to a central detector *(see Figure 8.3.2.4.4)* . Air sampling systems typically have a wide range of sensitivity, encompassing typical ranges of spot smoke detectors and including a much more sensitive range with smoke alarm levels over an order of magnitude lower. These systems are ~~commonly~~ often used in the protection of ~~high value~~ high-value occupancies ~~due to~~ because of their high sensitivity.

Figure 8.3.2.4.4 Use of Sampling Tubes to Convey Smoke-Laden Air to Central Detection Unit of Air-Sampling Detector. [72 Handbook: **Figure 17.31]**



8.3.2.4.5 Projected Beam.

Projected-beam smoke detectors consist of a light source projected onto a photosensitive receiver. The detector measures smoke based on the amount the light is obscured when smoke crosses the path of the light beam. Beam detectors are generally used to protect large open spaces with beam lengths upward of about 50 m to 150 m (160 ft to 500 ft).

8.3.2.5 Heat Detection.

8.3.2.5.1 Spot and Linear Heat Detectors.

There are ~~generally~~ two main types of heat detectors — spot ~~detection~~ detectors and linear ~~detection~~ detectors. Each type can respond to temperature via a fixed temperature threshold or a rate-of-rise temperature threshold. Heat detectors are not deemed life safety equipment and are primarily used for property protection, particularly in applications where smoke detection is not appropriate or not required. Spot heat detectors are routinely combined with smoke detectors in a singular device. Figure 8.3.2.5.1(a) through Figure 8.3.2.5.1(d) show examples of different types of heat detectors.

Figure 8.3.2.5.1(a) Electronic Spot-Type Heat Detector. [72 Handbook: **Figure 17.16]**

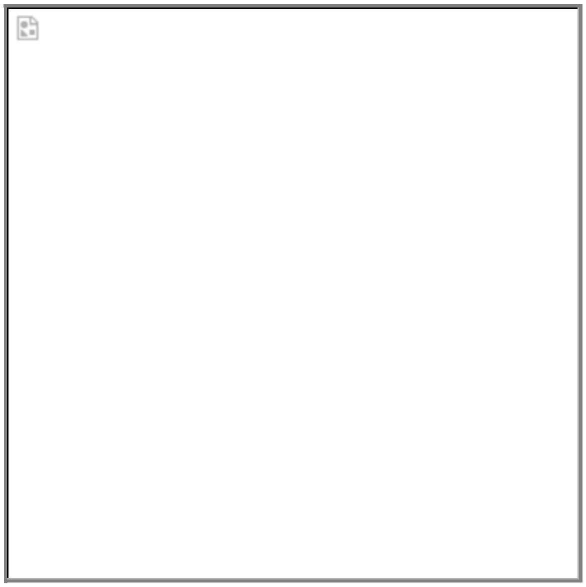


Figure 8.3.2.5.1(b) Spot-Type Fixed-Temperature Heat Detector. [72 Handbook: **Figure 17.18]**

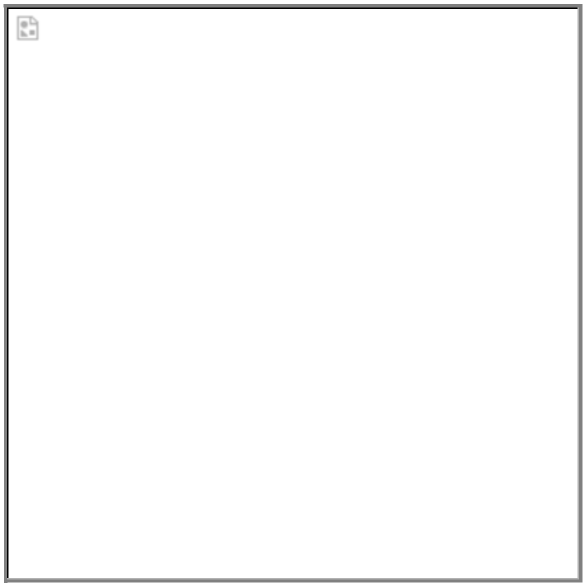


Figure 8.3.2.5.1(c) Line-Type Heat Detector. [72 Handbook: **Figure 17.19]**

Figure 8.3.2.5.1(d) Rate Compensation Heat Detector — Horizontal Mounting. [72 Handbook: **Figure 17.20]**

8.3.2.5.2 Radiant Energy-Sensing Fire Detector.

A device that detects radiant energy, such as ultraviolet, visible, or infrared~~, that is~~ emitted as a product of combustion reaction and obeys the laws of optics.

8.3.2.5.3 Flame Detectors.

A radiant energy detector that detects a flame. There are many types of flame detectors, with some ~~of them~~ capable of protecting a conical area, approximately ± 45 degrees in the vertical and ~~horizontal~~ extending a distance of up to 15 m (50 ft) to 60 m (200 ft) in the horizontal .

8.3.2.5.4 Spark/Ember Detectors.

Spark/ember detectors are installed to detect sparks or embers that could~~, if allowed to continue to burn, precipitate~~ result in a ~~much larger~~ fire or explosion. Typical applications ~~of these~~ include monitoring material as it passes through ducts or conveyers ~~to monitor fuel as it passes by~~. These devices typically work in the infrared spectrum and are intended to operate in dark environments.

8.3.2.6* Other Types of Detectors.

Various types of gas detectors are used in industrial/commercial and residential occupancies. Typical types include carbon monoxide (CO) and fuel gas, such as propane and hydrogen. In addition to independent detectors, some fire detection systems combine gas sensors, particularly CO, with other fire sensors, such as smoke, to provide multi-criteria detectors that have claimed advantages of improved detection and/or reduced nuisance alarms. The maintenance and calibration of gas detectors can be a critical aspect of performance.

8.3.2.7 Notification Appliances.

A *notification appliance* is a component of a fire alarm system ~~component~~ such as a bell, horn, speaker, light, or text display that provides audible, tactile, or visible outputs, or any combination thereof. Notification of an alarm can be provided within the protected area to alert occupants or at remote locations to alert facility staff or fire departments. Figure 8.3.2.7(a) through Figure 8.3.2.7(c) shows examples of notification devices.

Figure 8.3.2.7(a) Listed Notification Appliance. [72 Handbook: **Figure 18.1]**

Figure 8.3.2.7(b) Notification Appliance Showing Mechanical Baffle. [72 Handbook: **Figure 18.3]**

Figure 8.3.2.7(c) Audible Notification Appliance for High Ambient Noise Areas. [72 Handbook: **Figure 18.9]**

8.3.3* Operation and Installation Parameters of the System.

8.3.3.1 FACU Features.

The FACU is the central operating unit of the fire alarm system. The FACU receives, processes, and annunciates system signals, including alarm, supervisory, and trouble conditions. These signals can be stored in the FACU's electronic memory, communicated to a central monitoring service station, or recorded by a dedicated FACU printer. The FACU serves as means of acknowledging, silencing, and resetting all fire alarm system signals. A remote annunciator panel that displays the fire alarm system's operational status and current alarm conditions is sometimes located near the entrance to a building. The remote annunciator panel is an extension of the FACU and serves as a resource to first responders to assist with interpreting and locating alarm conditions.

8.3.3.2* Location and Spacing of Devices.

The location and spacing of initiating devices and notification appliances is addressed by manufacturer's instructions and standards such as *NFPA 72*~~,~~ ~~*National Fire Alarm and Signaling Code*~~ . Consideration should be given to initiating device spacing and mounting locations for challenging detection scenarios such as ~~abnormally high ceiling heights~~ ceilings higher than normal , ceilings with beams and joists, and sloped ceilings.

8.3.3.3 Internal System Communication.

Initiating devices and notification appliances can be connected to an FACU via ~~hard-wired~~ hardwired circuits or wireless communication. ~~Hard-wired~~ Hardwired fire alarm circuits serve as the means for powering, monitoring, and activating initiating device and notification appliance circuits.

8.3.3.4 Means of Alarm Transmission.

Fire alarm control panels can retransmit alarm signals to a supervisory station in a number of ways, including a dedicated circuit independent of any switching station, a one-way ~~(~~ outgoing~~)~~ telephone line, and via wireless transmission.

8.3.3.5 Systems Monitored and Controlled.

8.3.3.5.1 Central Station.

A *central station* is a supervising station ~~that is~~ listed for central station service ~~and~~ that also commonly provides less stringent supervisory station services, such as remote supervising services.

8.3.3.5.2 Proprietary Station.

A *proprietary station* is a supervising station under the same ownership as the protected premises fire alarm system(s) that it supervises ~~(~~ or monitors~~)~~ , and ~~to which~~ where alarm, supervisory, or trouble signals are received and where personnel are in attendance at all times to supervise operation and investigate signals.

8.3.3.5.3 Remote Station.

A *remote station* is a supervising station ~~to which~~ where alarm, supervisory, or trouble signals or any combination thereof emanating from protected premises fire alarm systems are received and where personnel are in attendance at all times to ~~respond~~ take action .

8.3.4* Analysis.

8.3.4.1 System Documentation and Data Collection.

Fire alarm system components, locations, and conditions should be documented and analyzed. Besides general documentation items noted in Section 8.2 , fire alarm systems should be documented with considerations to power supply, detector activation, notification activation, and integration with other systems. Other systems may include fire suppression, HVAC controls, door and barrier closures, elevator recall, and smoke control.

8.3.4.2 Code Analysis.

While codes enforced by various jurisdictions will vary from one jurisdiction to another, the base prescriptive code for fire alarm systems in most places is *NFPA 72* . The requirements of *NFPA 72* may be adopted as-is, or may be adopted with modifications by model codes such as the *International Building Code* or with variations put in place by local officials. Whenever a code analysis of a fire alarm system is conducted, the investigator should determine the following before proceeding with a code analysis:

(1) What code was in place when the building received its certificate of occupancy?

(2) Are there local amendments to that code? See the AHJ for this information.

(3) Were variances to the code granted during the design of the building based on performance-based analysis or some other justification? If so, design analysis reports should be available.

(4) What maintenance codes were in place during the lifetime of the fire alarm system?

(5) Does the insurance provider have additional fire alarm requirements that had an impact on the system design?

8.3.4.3 Design Analysis

8.3.4.3.1

Understanding the design of a fire alarm system is instrumental in determining what impact it may have had during a fire. Several important concepts in fire alarm system design are highlighted in 8.3.4.3.2 through 8.3.4.3.5 .

8.3.4.3.2

The position of fire alarm equipment, particularly initiating devices and notification appliances, can greatly impact performance. The detector location relative to the fire will influence the time to activation. The location of notification appliances relative to occupants will influence occupant response.

8.3.4.3.3

The evaluation of the appropriateness of equipment for the application is an integral part of the design. This may include the type of initiating device, the location and spacing, and the method of monitoring.

8.3.4.3.4

The system design needs to consider the power load of equipment, the circuit design, and the proper sizing of power supplies.

8.3.4.3.5

The notification system must account for issues of audibility and intelligibility as well as visibility.

8.3.4.4 Installation ~~Considerations~~ Analysis .

Installations should be compared to manufacturer recommendations, design drawings, and applicable codes and standards. Building features, access to devices, construction, renovations, and use of the facility should be considered when analyzing the performance of initiating devices and notification appliances.

8.3.4.5 Testing and Maintenance Analysis. (Reserved)

8.3.4.6 System Performance.

Performance of a system or device includes having appropriate power, conditions for operation, and functionality of the equipment. Performance may include an analysis of the time of activation of initiating devices and notification appliances, the functionality of interconnection with other systems, an occupant response to alarm notification, and transmission of and response to trouble and alarm signals.

8.3.4.6.1 Analysis of Smoke Alarm Response.

In fire reconstruction, knowledge of whether and when a particular smoke alarm sounded during the fire can be valuable data. Determination of alarm sounding may be possible from interviewing witnesses or first responders; however, smoke alarms, fire alarm system equipment, or notification appliances can often be damaged by the fire so that an alarm may not be ~~able to be~~ heard by the time ~~rescue personnel~~ first responders arrive. ~~Additionally~~ In addition , witnesses may simply not recall hearing an alarm during a fire incident, although an alarm may have sounded. Furthermore, in some cases, a physical exam of the smoke alarm may yield information regarding whether or not the smoke alarm had sounded through the identification of ~~acoustic agglomeration~~ enhanced deposition of soot around the sounder .

8.3.4.6.2 Analysis of Smoke Deposition.

In many cases, the nature of soot deposition on certain surfaces of typical single- and multi-station smoke alarms can show that the smoke alarm ~~sounded~~ did or did not sound during a fire. In addition, the color and consistency of these deposits may also aid in determining the type of fuel burned in a fire. Typically, the soot that will be deposited from a flaming fire will be a black carbon-based material. However, fuels such as polyurethane foam can produce orange tarry deposits during smoldering combustion. ~~For more information, see~~ *(See ~~Section~~ 6.2.10.3 ~~in Chapter 6~~ .)*

8.3.4.6.3* Alarm Response Time.

Computer models exist that can assist in the analysis of the response of fire detection and alarm equipment. Additional information on modeling can be found in Section 22.4 ~~in Chapter 22~~ .

8.3.4.6.4 Estimation of Fire Size.

It may be possible to use the activation or ~~non-activation~~ nonactivation of detectors to determine the fire's size at a given point in time. The minimum fire size necessary to activate the system can be estimated through testing or calculation. If the system did not activate, but was found to be properly designed and in working order, it may be possible to use this estimated fire size as the maximum fire size; whereas if the system did activate, a minimum fire size may be established. Knowing the maximum or minimum fire size can be an aid in determining the cause of the fire and means of its spread.

8.3.4.7 Development of Timeline.

If the detection and alarm system is connected to a monitored system, these records can be used to establish a timeline of ~~flame and fire spread~~ smoke and fire development . In some cases, the specific location or zone of the first alarming detector can be used to narrow down an area of origin. Some systems provide only alarm and trouble data, and do not specify a particular zone or device. This information can be helpful in comparing the time of system activation to the time and observations of first-arriving fire fighters or other witnesses, in assessment of the growth and spread of the fire. It can also be ~~observed~~ useful to know where and when manual alarms were activated; however, this information may be more indicative of the locations of building occupants and their escape routes rather than the actual location of the fire origin.

8.3.4.7.1

Accessing data from ~~a smoke~~ any alarm ~~system~~ panel should only be completed by a trained and competent individual to prevent the data from being corrupted or erased. Consideration should be given to the power condition of the system and damage to the system before attempts to access data are pursued. In some cases, if the system is still energized, the information should be collected before the panel is removed, as cutting the power may alter or erase the memory. However, powering up a damaged system ~~with damage~~ , either at the panel or along device circuits connected to the panel, may also cause the data to be altered or the system to be further damaged .

8.3.4.7.2

Alarm system data may also be collected from a central/remote monitoring station if the system was continuously monitored. Information from past incidents can also be collected from these stations. ~~When a zoned alarm system is present, the activated zones may be indicated through indicator lights at the main control panel. Efforts should be made to photograph this panel as early in the investigation as possible, as backup power for these panels often expires within days or even hours of loss of power to the building.~~

8.3.4.7.3

When a zoned alarm system is present, the activated zones may be indicated through indicator lights at the main control panel. Efforts should be made to photograph this panel as early in the investigation as possible, as backup power for these panels often expires within days or even hours of loss of power to the building.

8.3.4.8* Thermal Damage.

Thermal damage to ~~a smoke alarm sounder will~~ notification devices may reduce or eliminate ~~its~~ their ability to alert occupants. ~~An~~ Documentation and analysis of the thermal damage ~~can~~ may be ~~made~~ used to determine the ~~thermal~~ temperature level in the environment of the ~~alarm/sounder, such as temperatures reaching a certain level~~ devices .

8.3.4.9* Fire Alarm Effectiveness.

~~If it is determined that a notification appliance activated, yet sleeping occupants were not alerted, consideration must be made for the type of occupants.~~ Studies have been conducted on the waking effectiveness of notification appliances on various subjects, including those hard of hearing, elderly, children, and those with impaired judgment. ~~Other factors may influence the effectiveness of alarm systems, such as impairments of occupants through the use of drugs, alcohol and medications, mental and physical limitations, response and actions taken by occupants.~~ The reaction of an occupant to the alarm should also be evaluated, as the reaction could also be influenced by various impairments, such as the use of drugs or alcohol, or mental and physical limitations.

8.3.4.10 Impact on Human Behavior.

8.3.4.10.1*

The presence of active fire protection systems may have an impact on the behavior of the building occupants. Fire alarm systems are among the variables of built-in fire safety that may be critical to an individual's awareness of a fire. Research has shown that verbal, directive messages may be most effective in creating a response, compared to alarm bells and sounders alone.

8.3.4.10.2*

Prior false alarms and alarm system malfunctions may reduce the positive effect of having an alarm system in the building, because the occupants may not respond appropriately to the alarm notification. Numerous false alarms reduce the occupants' appropriate responses to the alarm.

~~**8.3.4.7** Operability.~~

~~Operability of a system or device includes having appropriate power, conditions for operation, and functionality of the equipment. Operability may include an analysis of the time of activation of initiating devices.~~

8.3.4.8 Analysis of Smoke Alarm Response.

In fire reconstruction, knowledge of whether and when a particular smoke alarm sounded during the fire can be valuable data. Determination of alarm sounding may be possible from interviewing witnesses or first responders; however, smoke alarms, fire alarm system equipment, or notification appliances can often be damaged by the fire that an alarm may not be able to be heard by the time rescue personnel arrive. Additionally, witnesses may simply not recall hearing an alarm during a fire incident, although an alarm may have sounded. Furthermore, in some cases, a physical exam of the smoke alarm may yield information regarding whether or not the smoke alarm had sounded through the identification of acoustic agglomeration of soot.

8.3.4.7 Analysis of Smoke Deposition.

8.3.4.7.1*

In many cases, the nature of soot deposition on certain surfaces of typical single- and multi-station smoke alarms can show that the smoke alarm sounded or did not sound during a fire. In addition, the color and consistency of these deposits may also aid in determining the type of fuel burned in a fire. Typically, the soot that will be deposited from a flaming fire will be a black carbon-based material. However, fuels such as polyurethane foam can produce orange tarry deposits during smoldering combustion. For more information, see Section 6.2.10.3 in Chapter 6 .

8.3.4.7.2* Alarm Response Time.

Computer models exist that can assist in the analysis of the response of fire detection and alarm equipment. Additional information on modeling can be found in Section 22.4 in Chapter 22 .

8.3.4.7.3 Estimation of Fire Size.

It may be possible to use the activation or non-activation of detectors to determine the fire's size at a given point in time. The minimum fire size necessary to activate the system can be estimated through testing or calculation. If the system did not activate, but was found to be properly designed and in working order, it may be possible to use this estimated fire size as the maximum fire size; whereas if the system did activate, a minimum fire size may be established. Knowing the maximum or minimum fire size can be an aid in determining the cause of the fire and means of its spread.

8.3.4.7.4 Development of Timeline.

If the detection and alarm system is connected to a monitored system, these records can be used to establish a timeline of flame and fire spread. In some cases, the specific location or zone of the first alarming detector can be used to narrow down an area of origin. Some systems provide only alarm and trouble data, and do not specify a particular zone or device. This information can be helpful in comparing the time of system activation to the time and observations of first-arriving fire fighters or other witnesses, in assessment of the growth and spread of the fire. It can also be observed where manual alarms were activated however this may be more indicative of the locations of building occupants and their escape routes than the actual location of the fire origin.

8.3.4.7.4.1

Accessing data from a smoke alarm system panel should only be completed by a trained and competent individual to prevent the data from being corrupted or erased. Consideration should be given to the power condition of the system and damage to the system before attempts to access data are pursued. In some cases, if the system is still energized, the information should be collected before the panel is removed, as cutting the power may alter or erase the memory. However, powering up a system with damage, either at the panel or along device circuits connected to the panel, may also cause the data to be altered.

8.3.4.7.4.2

Alarm system data may also be collected from a central/remote monitoring station if the system was continuously monitored. Information from past incidents can also be collected from these stations. When a zoned alarm system is present, the activated zones may be indicated through indicator lights at the main control panel. Efforts should be made to photograph this panel as early in the investigation as possible, as backup power for these panels often expires within days or even hours of loss of power to the building.

8.3.4.7.5* Thermal Damage.

Thermal damage to a smoke alarm sounder will reduce or eliminate its ability to alert occupants. An analysis of the thermal damage can be made to determine the thermal environment of the alarm/sounder, such as temperatures reaching a certain level.

8.3.4.7.6* Fire Alarm Effectiveness.

If it is determined that a notification appliance activated, yet sleeping occupants were not alerted, consideration must be made for the type of occupants. Studies have been conducted on the waking effectiveness of various subjects, including those hard of hearing, elderly, children, and those with impaired judgment. Other factors may influence the effectiveness of alarm systems, such as impairments of occupants through the use of drugs, alcohol and medications, mental and physical limitations, response and actions taken by occupants.

8.3.4.7.7 Impact on Human Behavior.

8.3.4.7.7.1*

The presence of active fire protection systems may have an impact on the behavior of the building occupants. Fire alarm systems are among the variables of built-in fire safety that may be critical to an individual's awareness of a fire. Research has shown that verbal, directive messages may be most effective in creating response, compared to alarm bells and sounders alone.

~~**8.3.4.7.7.2**~~*

~~Prior false alarms and alarm system malfunctions may reduce the positive effect of having an alarm system in the building, because the occupants may not respond appropriately to the alarm notification. Numerous false alarms reduce the occupants' appropriate responses to the alarm.~~

8.4 Water-Based Fire Suppression Systems.

8.4.1* General Information.

8.4.1.1 Purpose of Systems.

Water-based fire suppression systems are those that are designed to react at predetermined conditions, including temperatures or fire alarm activation, by releasing water and distributing it in specified patterns and quantities over designated areas. The distribution of water is intended to extinguish a fire or to prevent its spread.

8.4.1.2 General System Operation.

8.4.1.2.1 Extinguishment Mechanism.

Fire suppression methods use one or more mechanisms to extinguish or control a fire. The dominant extinguishment mechanism for water-based fire suppression systems is by cooling. Flaming combustion requires a high temperature ~~in order~~ for the chemical reactions to proceed. By reducing the amount of heat in the combustion zone, a fire can be controlled or extinguished. Figure 8.4.1.2.1 depicts fire control by a sprinkler system.

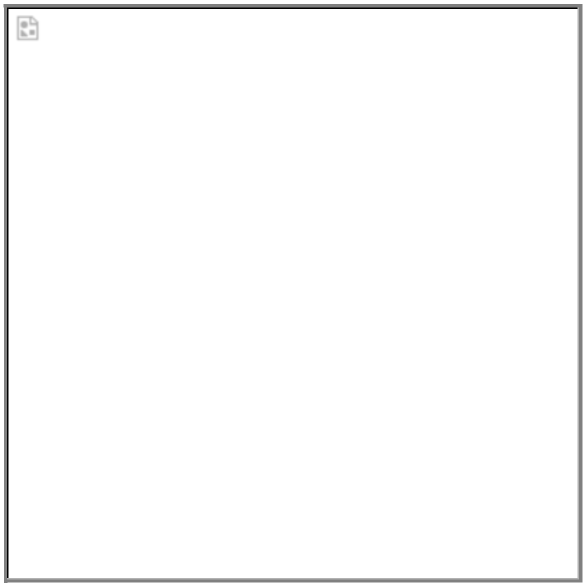
Figure 8.4.1.2.1 Fire Control by Sprinklers — Conceptual. [Fire Protection Handbook: **Figure 16.1.8]**

8.4.1.2.2* Types of Water-Based Systems.

8.4.1.2.2.1 Wet Pipe Sprinkler System.

A sprinkler system employing automatic sprinklers attached to a piping system containing water and connected to a water supply so that water discharges immediately from sprinklers opened by heat from a fire. Figure 8.4.1.2.2.1 depicts basic components of a wet pipe sprinkler system. [**13,**~~2013~~ 2016]

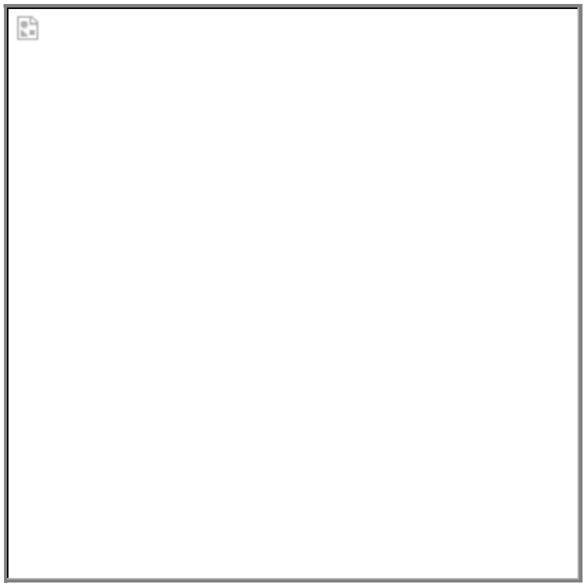
Figure 8.4.1.2.2.1 Basic Components of a Wet Pipe Sprinkler System. [Fire Protection Handbook: **Figure 16.3.8]**



8.4.1.2.2.2 Dry Pipe Sprinkler System.

A *dry pipe sprinkler system* is a sprinkler system employing automatic sprinklers that are attached to a piping system containing air or nitrogen under pressure, the release of which, ~~(~~ as from the opening of a sprinkler~~)~~ , permits the water pressure to open a valve known as a dry pipe valve, and the water then flows into the piping system and out the opened sprinklers. Figure 8.4.1.2.2.2 depicts the basic components of a dry pipe sprinkler system. [**13,**~~2013~~ 2016]

Figure 8.4.1.2.2.2 Hypothetical Dry Pipe System. [Fire Protection Handbook: **Figure 16.3.10]**



8.4.1.2.2.3 Preaction Sprinkler System.

A *preaction sprinkler system* is a sprinkler system employing automatic sprinklers that are attached to a piping system that contains air that might or might not be under pressure, with a supplemental detection system installed in the same areas as the sprinklers [**13,**~~2013~~ 2016]. Operation of the detection system allows the preaction valve to automatically open and admit water into the pipe network. Water will not discharge from the system until a fire has generated a sufficient quantity of heat to cause operation of one or more sprinklers. Figure 8.4.1.2.2.3 depicts basic components of a preaction sprinkler system.

Figure 8.4.1.2.2.3 Typical Preaction Sprinkler System. [Fire Protection Handbook: **Figure 16.3.11]**

8.4.1.2.2.4 Deluge Sprinkler System.

A *deluge sprinkler system* is a sprinkler system employing open sprinklers or nozzles that are attached to a piping system that is connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers or the nozzles. When this valve opens, water flows into the piping system and discharges from all sprinklers or nozzles attached thereto. Figure 8.4.1.2.2.4 depicts the basic components of a deluge sprinkler system. [**13,**~~2013~~ 2016]

Figure 8.4.1.2.2.4 Deluge System. [Fire Protection Handbook: **Figure 16.3.13]**

8.4.1.2.2.5 Water Mist Systems.

A water mist system is an automatic water-based fire protection system with nozzles capable of distributing water mist to a variety of hazards. The definition of a *water mist* is a fine water spray whose water droplets are less than 1000 microns at a distance of 3.3 ft from the discharge nozzle.

8.4.1.2.2.6 Foam Water Systems.

Foam systems are used to protect a variety of hazards, including those involving flammable liquids and enclosures such as the hulls of ships. Foam is generated by proportioning foam concentrate with water. Low-expansion foams work by covering burning materials with a blanket of foam. Medium- or high-expansion foams are used to fill enclosures.

8.4.1.2.3 Water Supply.

Each water-based fire protection system is supplied with water. The configuration of this supply and the components associated with the supply can vary widely. A detailed discussion of these water supplies is beyond the scope of this document.

8.4.2 Key Components of Water-Based Systems.

All required components for the successful operation of a water-based system must be listed by a nationally recognized testing laboratory.

8.4.2.1 Sprinklers/Nozzles.

Sprinklers and nozzles must be listed and labeled for the intended application. Sprinkler characteristics include the K-factor, ~~(~~ related to orifice size~~),~~ ; temperature rating~~,~~ ; orientation (e.g., pendant, upright, side-wall mounted)~~,~~ ; and applied coatings.

8.4.2.2 Piping.

A number of piping materials are acceptable for use in sprinkler systems, with steel, copper, and nonmetallic pipe materials ~~currently~~ addressed by NFPA 13~~, *Standard for the Installation of Sprinkler Systems*~~ . These pipe materials must meet certain pipe manufacturing standards, or certain listing requirements, or both. Nonmetallic pipe is only acceptable under limited conditions. NFPA 13 covers methods for how pipe is to be installed.

8.4.2.3 System Values.

Automatic sprinkler systems are required to have at least one valve installed to allow for the system to be shut down. Sprinkler systems should never be shut down except when system modifications are being conducted or during the time following a fire to allow for replacement of any sprinklers that operated.

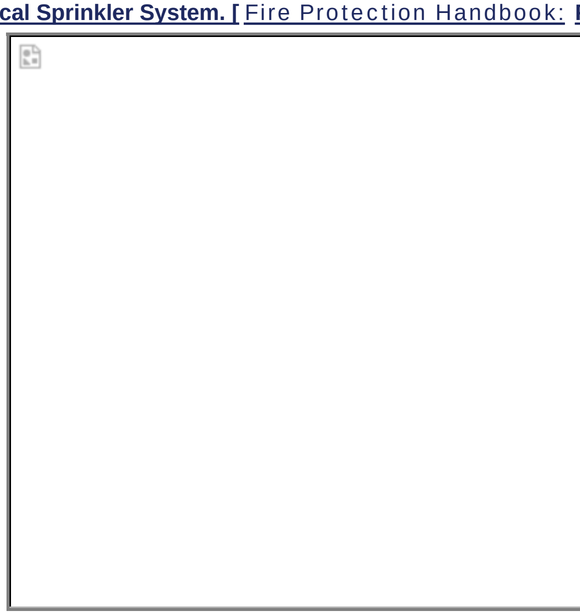
8.4.2.4 Water Supply.

8.4.2.4.1

Every automatic water-based fire suppression system must have at least one automatic water supply of adequate pressure, capacity, flow rate, and reliability. An automatic supply is one that is not dependent on any human intervention to manually operate valves, start pumps, or make connections to supply water at the time of a fire.

Figure 8.4.2.4.1 depicts a various water supply sources and attachments.

Figure 8.4.2.4.1 Hypothetical Sprinkler System. [Fire Protection Handbook: **Figure 16.3.7]**



8.4.2.4.2

The water can be supplied from a single source or a combination of sources such as municipal water supplies, elevated gravity tanks, at-grade tanks or reservoirs, pressure tanks, rivers, lakes, and ground well water.

8.4.2.4.3

Water supplies may require one or more pumps to supply the pressure required by the water-based fire suppression system.

8.4.3 Operation and Installation Parameters of the System.

8.4.3.1 Location and Spacing of Sprinklers.

8.4.3.1.1

Sprinklers are required to be installed in accordance with manufacturer's installation instructions and requirements found in the applicable codes and standards.

8.4.3.1.2

The requirements for location of sprinklers are based on the characteristics of the sprinklers and the hazard being protected. The higher the hazard, the closer the sprinklers are located to each other. Area of coverage can range from 8.4 m^2 (90 ft^2) per sprinkler for high-hazard occupancies to 21 m^2 (225 ft^2) per sprinkler for ~~light hazard~~ light-hazard occupancies. The larger coverage areas are only for hydraulically designed systems. In addition, there is also a maximum dimension between individual sprinklers. Extended coverage sprinklers, tested and approved for a larger distribution pattern, may be installed in accordance with the manufacturer's listing requirements. The maximum coverage is capped at 37.2 m^2 (400 ft^2).

8.4.3.1.3

Sprinkler location in relation to the floor or ceiling structure ~~is~~ are also controlled by ~~the~~ standards. Normally the deflector of a sprinkler is required to be between 1 and 12 in. (25 mm and 305 mm) from the structure. There are several exceptions based on specific conditions.

8.4.3.1.4

In a fully sprinklered building, sprinklers are located throughout the premises with very few explicit exceptions. If the construction is combustible, the sprinklers are required to be located within the combustible concealed spaces. There are several exceptions to this requirement based on very specific conditions, such as small discontinuous joist spaces.

8.4.3.2 Pipe Sizing and Arrangement.

8.4.3.2.1

Pipe sizing and arrangement are based on either the pipe schedule method or if the system needs to be hydraulically calculated. Modern systems are almost always hydraulically calculated. The pipe schedule system was the only means for determining pipe sizing until the 1970s. Existing pipe schedule systems may be extended using a pipe schedule, but the size of the expansion is limited by the standards.

8.4.3.2.2

A pipe schedule system is based on the concept of using larger pipes as more sprinklers are supplied. The pipe size starts at 25 mm (1 in.) and increases based on the number of sprinklers supplied by each piece of pipe.

8.4.3.2.3

A hydraulically designed system is sized based on the friction loss associated with the quantity of water flowing through the pipes and the water supply available. In a hydraulically calculated system, pipe sizes do not necessarily increase based on the number of sprinklers served. Frequently, the same size pipe is used for the majority of the system for ease of installation. More often, the pipe is sized to minimize the size of the pipe and the installation cost of the system. A pipe schedule system may be hydraulically calculated to determine if the water supply provided sufficient flow and pressure to protect the hazard present.

8.4.3.3 Sprinkler Coverage and Distribution.

8.4.3.3.1

Sprinklers have a distinct coverage and distribution. Based primarily on the characteristics of the deflector and the size of the sprinkler opening, the amount of water flowed, the size of the water droplets, the distance the water travels, and the consistency of the distribution are all determined.

8.4.3.3.2

~~Sprinklers~~ Per NFPA 13, sprinklers are required to uniformly distribute the water over the area they cover. Water droplet size affects the penetration of the water to the fire. The larger the fire, the larger the water droplet needed to counteract the upward buoyancy of the smoke and hot gases released from the burning materials. ~~The distance the water travels is directly related to the spacing allowances detailed in 8.4.3.1 through 8.4.3.3.1.~~ The amount of water is also critical because if it is less than needed, the fire will continue to develop, exceeding the capacity of the system to control it.

8.4.3.3.3

There are a variety of sprinklers to address different conditions. These sprinklers have particular distribution patterns and conditions for their use. Some examples are sidewall, extended ~~throw~~ coverage, large drop, and attic.

8.4.3.4 Water Flow Rate and Pressure.

8.4.3.4.1

Extinguishment of fires using water is based on several factors related to the hazard protected. The most critical is the quantity of water ~~required~~ necessary to extinguish or control the fire. This amount of water and the area over which it is distributed has been determined by numerous live fire tests over the last 100 years. ~~In order to~~ To provide the required water, each sprinkler needs to discharge a predetermined amount of water over the area that particular sprinkler protects. This number is referred to as the *design density*. To provide the ~~required~~ necessary design density, the sprinkler needs to be supplied by a flow and pressure. The normal minimum pressure at the most remote sprinkler is 0.5 bar (7 psi). The higher the pressure at the sprinkler, the more flow. The required minimum pressure for some hazards can exceed several times this minimum.

8.4.3.4.2

The summation of the flows from all the sprinklers and the friction losses in the pipes as a result of the water flowing through them results in a required flow and pressure for the system. This flow and pressure is normally referenced to the base of the riser. The water supply to the system must meet or exceed the required flow and pressure. If not, the water distributed on the hazard may be insufficient to control or extinguish the fire.

8.4.3.5 Activation Mechanisms and Criteria.

8.4.3.5.1

~~Water based~~ Water-based systems can be activated in a variety of ways. Some systems have closed sprinklers with fusible elements or glass bulbs, others have open sprinklers with a means of controlling water flow at the source, and others use a combination of closed sprinklers and remote control of the water flow.

8.4.3.5.2

Closed sprinklers with fusible elements activate when the temperature at the head exceeds the rated temperature of the fusible element and the linkage that holds back the water is ejected from the sprinkler. A closed head has a~~n~~ response time index (RTI) ~~(response time index)~~ associated with it. This is a number that relates to the speed at which it activates when exposed to temperatures above its rating. The time to activation can vary by a factor of ten. A sprinkler with a lower RTI should react faster than one with a higher RTI. The temperature rating of a sprinkler can be as low as 57°C (135°F) to 260°C (500°F) . Lower temperature sprinklers with low RTIs should be the fastest to activate.

8.4.3.6 Systems Monitored and Controlled.

8.4.3.6.1

Systems are monitored for water flow to alert interested parties that the system has operated. Valves controlling the water supply to the system may be monitored to allow interested parties to know the system is fully in service or that a portion of the system is out of service. This monitoring is normally accomplished by connection to the fire alarm system. In many instances there are only electrical or mechanical means of sounding a local alarm when the water flows in the system.

8.4.3.6.2

As indicated in 8.4.3.5 through 8.4.3.6.1 , ~~pre-action~~ preaction and deluge systems rely on other means of detection, either automatic or manual, to control the water supply to the nozzles. The means of detection should be matched to the characteristics of the hazard protected and the needs associated with the operation or occupancy.

8.4.4 Analysis.

8.4.4.1 System Documentation and Data Collection.

8.4.4.1.1

Care should be taken during the documentation and analysis of water-based fire suppression systems after a fire or explosion event. The whole system should be photo documented as soon as possible. Manipulating valves, removing components, resetting alarms, and so forth can be potentially destructive. Those with system expertise should be involved in any activities which could alter or destroy data about the system or its performance.

8.4.4.1.2

Evidence may include sprinkler design documents, plans, alarm history, panel data, and inspection, testing, and maintenance records. These documents should be secured and maintained.

8.4.4.2 Code Analysis.

8.4.4.2.1

While codes enforced by various jurisdictions will vary from one jurisdiction to another, the base prescriptive code for water-based fire suppression systems in most places is NFPA 13~~, *Standard for the Installation of Sprinkler Systems*~~ . Additional codes are available for the installation of sprinkler systems in one- and two-family dwellings and manufactured homes, and in residential occupancies up to four stories in height. Other prescriptive codes provide guidance on such issues as standpipe and hose systems, water spray systems, foam-enhanced systems, and a number of other topics. The requirements of these codes may be adopted as-is, or may be adopted with modifications by model codes such as the *International Building Code* or with variations put in place by local officials. Whenever a code analysis of water-based fire suppression systems is conducted, the investigator should determine the following before proceeding with a code analysis:

(1) What code was in place when the building received its certificate of occupancy?

(2) Are there local amendments to that code? (~~see~~ See the AHJ for this information~~)?~~ .

(3) Were variances to the code granted during the design of the building based on performance-based analysis or some other justification? If so, design analysis reports should be available.

(4) What maintenance codes were in place during the lifetime of the suppression system?

(5) Does the insurance provider have additional suppression requirements that had an impact on the system design?

8.4.4.3 Design Analysis.

8.4.4.3.1

Understanding the design of water-based fire suppression systems is instrumental in determining what impact it may have had during a fire. Several important concepts ~~in water based fire suppression system design are highlighted in 8.3.1.1 through 8.3.3.6~~ are discussed in 8.4.4.3.2 to 8.4.4.4.7 .

8.4.4.3.2 Placement.

The position of the water spray nozzle or sprinklers will greatly impact its ability to provide water that can penetrate to the seat of a fire. NFPA 13~~, *Standard for the Installation of Sprinkler Systems* ,~~ provides detailed recommendations for spacing and placement of sprinklers. In practice, several placement issues arise during or after installation that can have a negative~~ly~~ impact on the effectiveness of the suppression system, such as the following :

(1) Installation of hanging light fixtures under branch lines

(2) Installation of suspended ceilings below sprinklers, which (obstruct~~ing~~s the water spray~~)~~ , or above sprinklers, which can ~~(sometimes creating~~ create concealed combustible ~~concealed~~ spaces~~)~~

(3) Installation of high shelving

(4) Installation of rack storage shelving

(5) Reconfiguration of walls or addition of mezzanine floors

8.4.4.4 Hazard Protected.

8.4.4.4.1 Level of Hazard.

Water-based fire suppression systems are generally designed to protect against a certain level of hazard. NFPA 13~~,~~ ~~*Standard for the Installation of Sprinkler Systems*~~ uses hazard groups such as “Light,” “Ordinary,” “Extra Hazard,” and “Special Occupancy.” The level of hazard will determine the density of water that should be provided by the suppression system to protect against that hazard. *(See Figure 8.4.4.4.1.)*

Figure 8.4.4.4.1 Density/Area ~~Curves from NFPA 13~~. [13: Figure 11.2.3.1.1]

8.4.4.4.2 Changes Affecting Hazard Classification.

Typically, problems with hazard classification occur when the use of a building is changed, but its fire suppression system is not. For example, if an industrial building originally used as a bakery ordinary hazard) was bought by a new company and converted for use in plastics processing (extra hazard), then the existing fire suppression system would need to be upgraded. If this upgrade does not occur, a fire experienced by the new company may not be controlled by the old system.

8.4.4.4.3 Capacity.

Water-based fire suppression systems are designed to provide a predetermined density of water over an area that has been calculated based on the design hazard that is being protected. For example, one design might require that a density of 6.1 mm/min (0.15 gpm/ft^2) will be provided over an area of application of 139 m^2 (1500 ft^2) . If in this case the sprinkler to be used was listed with a coverage area of 10 ft by 13 ft 12.9 m^2 (130 ft^2), the system would need to be able to handle the activation of up to 12 sprinklers (i.e., 1500/130 rounded up). Additional capacity would also then be added to the system to account for hose streams that may be needed for suppression. Information regarding the system design capacity can be useful during an investigation for a number of reasons. If a number of sprinklers have activated greater than what the design called for, a number of problems could be indicated, among them including the following :

(1) The fuel load was more hazardous than originally expected during the system design of the system .

(2) The growth rate of the fire was faster than expected.

(3) Insufficient water was available to the system, potentially indicating issues with tampering with valves, lack of proper system maintenance, or reduction in available water supply subsequent to commissioning of the system.

(4) Obstructions were present (e.g., lights, shelving, etc. and so forth) that prevented the water spray from reaching the seat of the fire.

(5) Unusual circumstances, such as drop-down from a fire on the roof of a warehouse through multiple skylights causing a large number of sprinkler activations.

8.4.4.4.4 Coverage.

8.4.4.4.4.1 Amount of Building Coverage.

Knowing the amount of building coverage of the fire protection system will aid the investigator in analyzing the amount of damage caused by the fire, as well as the fire spread patterns.

8.4.4.4.4.2 Total (or Complete) Coverage.

Where *Total or complete coverage* is where a fire protection system covers all rooms, halls, storage areas, basements, attics, lofts, spaces above suspended ceilings, and other subdivisions and accessible spaces, as well as the inside of all closets, elevator shafts, enclosed stairways, dumbwaiter shafts, and chutes.

8.4.4.4.4.3 Partial or Selective Coverage.

Where *Partial or selective coverage* is where a fire protection system covers only a portion of the selected areas. An example of partial or selective coverage is the absence of sprinklers in combustible attics and bathrooms allowed by NFPA 13D and NFPA 13R .

8.4.4.4.4.4 Local Coverage.

Where Local coverage is where a fire protection system protects a particular location only, such as a certain piece of equipment. These systems are typically referred to as water spray systems and use open nozzles in combination with heat or flame detection systems.

8.4.4.4.4.5 Installation Analysis.

Installation analysis of water-based fire suppression systems should be conducted by an engineer or other design professional that is familiar with the requirements of the applicable codes, as well as with any variances that may be in place for that design. Typically, it is most efficient to conduct an installation analysis by starting at the incoming water supply and moving downstream along the system, noting pipes, valves, risers, nozzles/sprinklers, and other system components along the way. Common installation issues include use of incorrect sprinkler types (e.g., pendants installed in the upright position) and improper installation of valves.

8.4.4.4.4.6 Testing and Maintenance.

Routine testing and maintenance are important to the successful operation of a water-based fire suppression system. Local building codes contain requirements for testing and maintenance and should be referenced during a system analysis. Testing and maintenance records should be maintained by the company that has performed them; data pertinent to these inspections should be provided on tags located near the main system valves.

8.4.4.4.4.7 System Performance.

System performance is analyzed in much the same way as system installation. Several subcategories of system performance can be helpful in providing insight into the analysis of a specific fire or explosion event.

(A) Origin and Cause Determination.

A number of useful data points relevant to the testing of hypotheses associated with the origin and cause of a fire that can be obtained through analysis of the activation or non-activation nonactivation of a water-based fire suppression system.

(B)* Estimation of Fire Size.

Methods are available for estimating the size of a fire at the time of the first sprinkler activation. For , including for systems activated by an element with an response time index (RTI) , such as a thermally fusible linkage or frangible glass bulb, there are methods for estimating the fire size at the time of the first sprinkler activation. .

(C)* Fire Modeling.

A variety of computer models are available that may be used to calculate the activation time of a suppression system and in some cases its potential impact on fire development. Regardless of which model is used, engineering guidelines for substantiating a fire model for a given application should be employed.

~~**8.4.4.4.4.8** Testing and Maintenance.~~

~~Routine testing and maintenance are important to the successful operation of a water-based fire suppression system. Local building codes contain requirements for testing and maintenance and should be referenced during a system analysis. Testing and maintenance records should be maintained by the company that has performed them; data pertinent to these inspections should be provided on tags located near the main system valves.~~

~~**8.4.4.4.4.9** Origin and Cause Determination.~~

~~A number of useful data points relevant to the testing of hypotheses associated with the origin and cause of a fire that can be obtained through analysis of the activation or non-activation of a water-based fire suppression system.~~

~~**8.4.4.4.4.10** Timelines.~~

~~Many fire suppression systems are connected to an alarm system. These systems may provide alarm times to a central monitoring service, or at least to the hard drive of a local alarm panel. Minimally, a water-based fire suppression system would provide an alarm upon start of water flow. In more complex systems, there may be multiple water supply zones that can help pinpoint which parts of the system were flowing water at different times. Other timeline information may also be available, such as time that valves were opened/closed (via tamper alarms) or other supervisory/trouble signals specific to that system. An effort should be made to synchronize any alarm system time data with other investigative time data with a common clock.~~

~~**8.4.4.4.4.8*** Estimation of Fire Size.~~

~~Methods are available for estimating the size of a fire at the time of the first sprinkler activation. For systems activated by an element with a response time index (RTI), such as a thermally fusible linkage or frangible glass bulb, there are methods for estimating the fire size at the time of the first sprinkler activation.~~

8.4.4.4.4.8 Timelines.

Many fire suppression systems are connected to an alarm system. These systems may provide alarm times to a central monitoring service, or at least to the hard drive of a local alarm panel. ~~Minimally~~ At a minimum , a water-based fire suppression system would provide an alarm upon start of water flow. In more complex systems, there may be multiple water supply zones that can help pinpoint which parts of the system were flowing water at different times. Other timeline information may also be available, such as tamper alarms that indicate what time ~~that~~ valves were opened/closed ~~(via tamper alarms)~~ or other supervisory/trouble signals specific to that system. An effort should be made to synchronize any alarm system time data ~~with~~ and other investigative time data with a common clock.

8.4.4.4.4.9 Impact on Human Behavior.

The presence of automatic fire suppression systems, if known, may affect behavior. The effect may be positive or negative. A positive effect is that the increased margin of safety of such systems provides occupants of the involved structure more time to respond ~~appropriately~~ to the hazards presented by the incident. An example of a negative effect is possible decreased visibility caused by the discharge of the suppression agent, which may impede egress.

~~**8.4.4.4.5*** Fire Modeling.~~

~~A variety of computer models are available that may be used to calculate the activation time of a suppression system and in some cases its potential impact on fire development. Regardless of which model is used, engineering guidelines for substantiating a fire model for a given application should be employed.~~

8.5 Non-Water-Based Fire Suppression Systems.

8.5.1* General Information.

8.5.1.1 Purpose of Systems.

Gaseous and chemical fire suppression systems are specialty fire suppression systems using fire suppression medium other than water for special, specific hazards or equipment. These systems are commonly installed to protect things such as commercial cooking operations, vessel engine rooms, heavy equipment engine compartments, telecommunications and data rooms, quench tanks, and flammable liquid operations.

~~**8.5.1.2** System Components.~~

~~Gaseous and chemical fire suppression systems are engineered systems designed to protect a specific area or equipment, or for a specific hazard. The components of the system will specifically relate to the design of the system and the choice of suppression agent.~~

8.5.1.2 Method of Application.

Gaseous and chemical fire suppression systems are applied in one of two basic methods. One method is to discharge a sufficient amount of agent into an enclosure to create an extinguishing atmosphere throughout the enclosed area. This is called “total flooding.” The second method is to discharge the agent directly onto the burning material. This is called “local application.” With total flooding systems an important consideration is the integrity of the enclosed area. The area must be “tight” enough to hold the agent concentration long enough to affect extinguishment and prevent reignition.

8.5.1.3 Suppression Agents.

8.5.1.3.1 Halons and ~~Halon Replacements~~ Clean Agents .

Halon 1301 (bromotrifluoromethane or $CBrF_3$) is a colorless, odorless, electrically nonconductive gas that is an effective medium for extinguishing fires. Halon 1301 is included in the Montreal Protocol on Substances That Deplete the Ozone Layer, signed September 16, 1987. The protocol permits continued availability of halogenated fire extinguishing agents at 1986 production levels. That protocol, and subsequent amendments, restricts the production of this agent. In addition, local jurisdictions within some countries (e.g., the EPA in the United States) have enacted further rules regulating the production, use, handling, and deposition of this agent. The term *clean agent* is used to describe a family of inert gas fire suppressants that have replaced Halon 1301. Clean fire suppression agents are defined as fire extinguishants that vaporize readily and leave no residue. They are also electrically nonconductive. Table 8.5.1.3.1 summarizes currently available clean fire suppression agents included in NFPA 2001 .

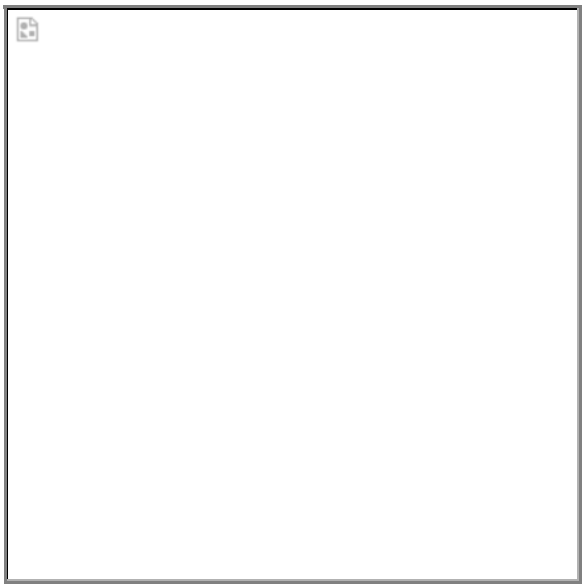
Table 8.5.1.3.1 Clean Fire Extinguishing Agents in NFPA 2001. [**Fire Protection Handbook:** Table 17.6.2]

FC-2-1-8	Perfluoropropane	C_3F_8
FC-3-1-10	Perfluorobutane	C_4F_{10}
FIC-13I1	Trifluoroiodide	CF_3I
FK-5-12mmy2	Dodecafluoro-2-methylpentan-3-one	$CF_3CF_2C(O)(CF(CF_3)_2)$
HCFC Blend A	Dichlorotrifluoroethane HCFC-123 (4.75%)	$CHC_{12}CF_3$
	Chlorodifluoromethane HCFC-122 (82%)	
	Chlorotetrafluoroethane HCFC-124 (9.75%)	
	Isopropeny-1-methylcyclohexene (3.75%)	
HCFC-124	Chlorotetrafluoroethane	$CHCIFCF_3$
HFC-125	Pentafluoroethane	CHF_2CF_3
HFC-227ea	Heptafluoropropane	CF_3CHFCF_3
HFC-23	Trifluoromethane	CF_3CHFCF_3
HFC-236fa	Hexafluoropropane	CF_3CH2CF_3
IG-01	Argon	Ar
IG-100	Nitrogen	N_2
IG-541	Nitrogen (52%)	N_2
	Argon (40%)	Ar
	Carbon dioxide (8%)	CO_2
IG-55	Nitrogen (50%)	N_2
	Argon (50%)	Ar

8.5.1.3.2 ~~Inert Gases~~ Carbon Dioxide .

Carbon dioxide is a standard commercial product with many uses. For fire-extinguishing applications, carbon dioxide has a number of desirable properties. It is noncorrosive and ~~non-damaging~~ nondamaging , and leaves no residue to clean up after the fire. It provides its own pressure for discharge through pipes and nozzles. Because it is a gas, it will penetrate and spread to all parts of a hazard. It will not conduct electricity and can therefore be used on live electrical hazards. It can effectively be used on practically all combustible materials except for a few active metals and metal hydrides, and materials~~, such as cellulose nitrate,~~ that contain available oxygen, such as cellulose nitrate . ~~Under normal conditions, carbon dioxide is an odorless, colorless gas with a density about 50 percent greater than the density of air. Many people insist they can detect an odor of carbon dioxide, but this could be due to impurities or chemical effects in the nostrils. Carbon dioxide is easily liquefied by compression and cooling. By further cooling and expansion, it can be converted to a solid state.~~ Carbon dioxide has been used for nearly a century to extinguish flammable liquid fires, gas fires, and fires involving energized electrical equipment. Carbon dioxide agent is stored in high-pressure cylinders or in low-pressure refrigerated. Because of its effects on humans, a life safety analysis is needed as part of the decision to employ this agent. Figure 8.5.1.3.2 shows a local application discharge test on a printing press.

Figure 8.5.1.3.2 Local Application Discharge Test on Printing Press. [Fire Protection Handbook: **Figure 17.1.11]**



8.5.1.3.3 Dry Chemical.

A dry chemical extinguishing agent is a finely divided powdered material that has been specially treated to be water repellent and capable of being fluidized and free-flowing so that it can be discharged through hose lines and piping when under expellant gas pressure. The dry chemicals produced by various manufacturers usually are not identical in all characteristics, and each manufacturer designs equipment for use with a specific dry chemical. System design principles applicable to the products of one manufacturer are not applicable to the products of another manufacturer. As a result, it is not practical to include system design details as a part of this guide. It is now generally accepted that the flame-extinguishing properties of dry chemicals are due to the interaction of the particles, which stop the chain reactions that take place in flame combustion. Dry chemicals vary in their flame-extinguishing effectiveness. Dry chemical is primarily used to extinguish flammable liquid fires. Multipurpose dry chemical owes its effectiveness in extinguishing fires involving ordinary combustibles, such as wood and paper, to the formation of a glow-retarding coating over the combustible material. The methods of dry chemical application are depicted in Figure 8.5.1.3.3(a) . The term dry chemical is not interchangeable with the term dry powder. Dry powder agents are developed primarily for use on Class D fires. Figure 8.5.1.3.3(b) shows the agent containers and discharge mechanism of a typical dry chemical system. Dry chemicals currently in use are described in 8.5.1.3.3.1 through 8.5.1.3.5.

Figure 8.5.1.3.3(a) Methods of Dry Chemical Application. [Fire Protection Handbook: **Figure 17.2.3]**

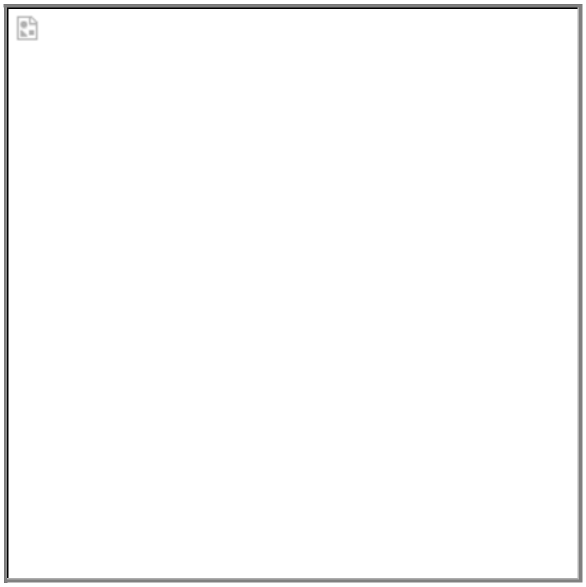
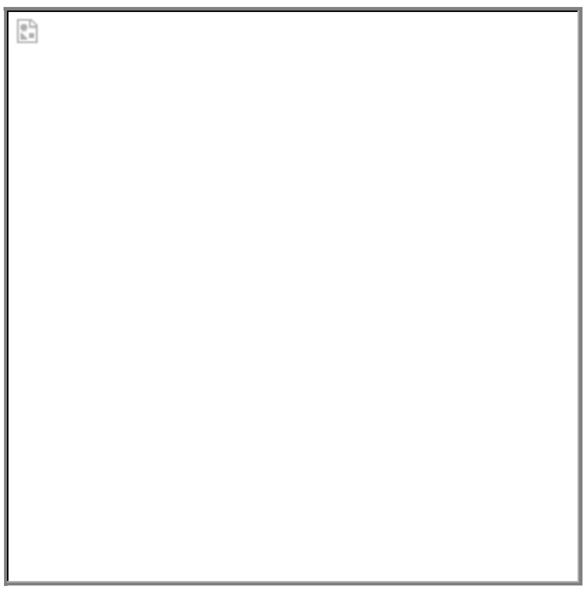


Figure 8.5.1.3.3(b) Methods of Dry Chemical Application. [Fire Protection Handbook: **Figure 17.2.4]**



8.5.1.3.3.1 Sodium ~~Bicarbonate-Based~~ Bicarbonate–Based Dry Chemical.

This agent consists primarily of sodium bicarbonate ($NaHCO_3$) and is suitable for use on all types of flammable liquid and gas fires (Class B) and for fires involving energized electrical equipment (Class C). ~~It is particularly effective on fires in common cooking oils and fats.~~ In combination with these materials, the sodium ~~bicarbonate-based~~ bicarbonate–based agent reacts to form a type of soap (i.e., saponification), which floats on a liquid surface~~,~~ ~~such as in deep-fat fryers,~~ and effectively prevents ~~re-ignition of the grease~~ reignition . Sodium ~~bicarbonate-based~~ bicarbonate–based dry chemical is not generally recommended for the extinguishment of fires in ordinary combustibles (Class A), although it can have a transitory effect in extinguishing surface flaming of such materials.

8.5.1.3.3.2 Dry Chemicals Based on the Salts of Potassium.

Commercially available agents are essentially potassium bicarbonate ($KHCO_3$), potassium chloride (KCl), and urea-based potassium bicarbonate ($KC_2N_2H_3O_3$). All three agents are suitable for use on all types of flammable liquid and gas fires (Class B) and also for fires involving energized electrical equipment (Class C). It is generally recognized that ~~salts of~~ potassium salts are more effective in terms of chemical extinguishment mechanisms than sodium salts in extinguishing Class B fires, except those in deep-fat fryers and other cooking equipment. Dry chemicals based on ~~the salts of~~ potassium salts are not generally recommended for the extinguishment of fires in ordinary combustibles (Class A), although they can have a transitory effect in extinguishing surface flaming of such materials.

8.5.1.3.3.3 Multipurpose Dry Chemical.

This agent has monoammonium phosphate ($NH_4H_2PO_4$) as its base and is similar in its effect on Class B and Class C fires to the other dry chemicals. However, it does not possess a saponification characteristic and should not be used on fires in deep-fat fryers. Unlike the other dry chemicals, it does have a considerable extinguishing effect on Class A materials. The agent, when heated, decomposes to form a molten residue that will adhere to heated surfaces. On combustible solid surfaces (Class A), this characteristic excludes the oxygen necessary for propagation of the fire.

~~**8.5.1.3.3.4** Foam-Compatible Dry Chemicals.~~

~~When or where foam dry chemical systems are used or proposed for the protection of a hazard, the manufacturer should be consulted as to the compatibility of the agents.~~

8.5.1.3.4 Wet Chemical.

A wet chemical solution generally includes, but is not limited to, a potassium carbonate–based, potassium acetate–based, potassium citrate–based solution, or a combination thereof, and is mixed with water to form an alkaline solution capable of being discharged through piping or tubing when under expellant gas pressure. The solution's effect on fires in common cooking oils and fats is to combine with these materials to form a vapor suppression foam that floats on a liquid surface, such as in deep-fat fryers, and effectively prevent ~~re-ignition~~ reignition of the grease. Wet chemical agents have replaced dry chemicals as the agent commonly used in commercial cooking applications. Wet chemical systems are local application systems. Figure 8.5.1.3.4 depicts a typical restaurant installation.

Figure 8.5.1.3.4 Examples of Commercial Kitchen Cooking Equipment Protected by a Nozzle. [Fire Protection Handbook: **Figure 17.2.5(b)]**

8.5.1.3.5 Expansion Foam.

Foam systems produce an expanding blanket of foam that is delivered to the fuel surface that physically isolates the fuel from the flame, blocks the admission of air ~~required~~ necessary for continuing the combustion process, and provides some cooling of the surface. Foams are classified according to their ratio of expansion and fall into three major categories: low expansion (up to 20:1), medium expansion (20:1 to 200:1), and high expansion (200:1 to 1000:1). Available foams include protein-based (P), fluoroprotein bases (FP and FFP), aqueous film-forming foam (AFFF), alcohol-resistant concentrates (AR), and chemical foams.

8.5.1.3.6 Condensed and Dispersed Aerosols.

A condensed aerosol is defined as an extinguishing medium consisting of finely divided solid particles, generally less than 10 microns in diameter, and gaseous matter, generated by a combustion process of a solid aerosol-forming compound. A dispersed aerosol is defined as an extinguishing medium consisting of fine particles of chemicals, generally less than 10 microns in diameter, already resident inside a pressurized agent storage container, suspended in a halocarbon or an inert gas. Systems using these agents can be either total flooding or local application.

8.5.2 Key Components of Systems.

8.5.2.1 Suppression Agent Supply.

Non-water-based fire suppression systems all involve a limited supply of agent. The number and size of the agent containers determine the supply. Containers ~~shall~~ should be designed and manufactured to store the agent used by the system. On occasion, such as for gaseous suppression agents, the agent may be stored under pressure.

8.5.2.2 Pressure Sources.

For some systems, particularly dry chemical suppression systems, an associated pressure source, often an inert gas such as carbon dioxide or nitrogen, is used to pressurize the system and deliver the chemical suppressant to the fire.

8.5.2.3 Distribution Piping.

The distribution piping ~~should be~~ is designed and constructed of material compatible with the characteristics of the suppression agent used, the pressure source being used, and the environment being protected.

8.5.2.4 Valves, Hoses, and Fittings.

All valves, hoses, fittings, and associated equipment must be listed and labeled for the purpose for which they are being used.

8.5.2.5 Proportioners.

In the case of expanding foam systems, a proportioning valve is used to mix the foam concentrate with water in specified ratios. Commonly encountered proportioning methods use the venturi effect or pressure to meter the concentrate into the system in the appropriate proportions. Figure 8.5.2.5(a) shows a schematic of a venturi proportioner. Figure 8.5.2.5(b) shows a balanced pressure proportioner.

Figure 8.5.2.5(a) Venturi Induction or In-Line Proportioner. [Fire Protection Handbook: **Figure 17.4.3]**

Figure 8.5.2.5(b) Skid-Mounted Balanced Pressure Proportioner. [Fire Protection Handbook: **Figure 17.4.9]**

8.5.2.6 Distribution Nozzles.

Distribution nozzles and monitors can be fixed or portable, and are often designed for use with a specific manufacturer's system. Figure 8.5.2.6(a) depicts a common distribution nozzle of a wet chemical system protecting cooking surfaces. Figure 8.5.2.6(b) depicts nozzles discharging carbon dioxide.

Figure 8.5.2.6(a) Wet Chemical Nozzles with Required Caps Protecting Against Clogging from Grease-Laden Vapors. [Fire Protection Handbook: **Figure 17.2.9]**

Figure 8.5.2.6(b) Discharge of a Local Application Carbon Dioxide Extinguishing System. [Fire Protection Handbook: **Figure 17.1.3]**

8.5.2.7 Actuation System.

Gaseous and chemical-based systems can be activated in a variety of ways. Some systems utilize automatic sensing devices with electrical or mechanical releases to flow the system. These systems can include sensors that are part of the fire detection and alarm system. Manual actuation devices are often present as well~~.~~ *(see Figure 8.5.2.7)* .

Figure 8.5.2.7 Clearly Identified Manual Pull Station. [Fire Protection Handbook: **Figure 17.2.7]**

8.5.2.8 System Monitoring and Control.

Systems are monitored for suppressant flow to alert interested parties that the system has operated. Valves controlling the suppressant supply to the system may be monitored to allow interested parties to know the system is fully in service or that a portion of the system is out of service. This monitoring is normally accomplished by connection to the fire alarm system. Some total flooding gaseous systems and some local application gaseous systems are connected to a control panel that, among other control processes, ensures that a ~~pre-discharge~~ predischarge time and alarm is present before flow of the suppressant to ensure life safety. Systems may also be required to shut off fuel and/or heat sources. Figure 8.5.2.8 depicts a gas shut-off valve that closes on actuation of the extinguishing system.

Figure 8.5.2.8 Typical Gas Shut-Off Valve That Closes on Actuation of the Extinguishing System. [Fire Protection Handbook: **Figure 17.2.8]**

8.5.3 Operation and Installation Parameters of the System.

8.5.3.1 Location and Spacing of Nozzles.

Nozzles for distributing extinguishing agents are required to be installed in accordance with manufacturer's Manufacturer's installation instructions and the applicable codes and standards contain the requirements found in the applicable codes and standards for the installation of nozzles for distributing extinguishing agents . The requirements for the location of nozzles are based on the characteristics of the nozzles and the hazard being protected. The more severe the hazard, the closer the nozzles are located to each other.

8.5.3.2 Pipe Sizing and Arrangement.

Pipe sizing and arrangement are based on either the specifications for pre-engineered systems or systems that are hydraulically calculated. A hydraulically designed system is sized based on the required flow rate and friction loss associated with an agent flowing through the distribution piping and nozzles.

8.5.3.3 Nozzle Coverage and Distribution.

Nozzles have a distinct coverage and distribution, which are primarily based on the characteristics of the nozzle and local system pressure. There are a variety of nozzles to address different coverage and distribution conditions such as “total flooding” and “local application” of fire suppression agent.

8.5.3.4 Activation Mechanisms and Criteria.

Non-water-based systems can be activated through activation of separate fire detection (e.g., smoke alarm system) or a detection system that is integrated into the suppression system (e.g., local thermal element).

8.5.3.5 Systems Monitored and Controlled.

Systems are monitored for fire detection and agent flow to alert interested parties that the system has operated. Valves controlling the agent supply to the system may be monitored to allow interested parties to know the system is fully in service or that a portion of the system is out of service. This monitoring is normally accomplished by connection to the fire alarm system. In many instances there are only electrical or mechanical means of sounding a local alarm when the water flows in the system.

8.5.4 Analysis.

8.5.4.1*

While codes enforced by various jurisdictions will vary from one jurisdiction to another, the prescriptive codes related to non-water-based fire suppression systems in most jurisdictions are incorporated in the NFPA *National Fire Codes*. The requirements of these codes may be adopted as-is, or may be adopted with modifications by model building codes such as the *International Building Code* or with variations put in place by local AHJs. Whenever a code analysis of non-water-based fire suppression systems is conducted, the investigator should determine the following before proceeding with a code analysis:

(1) What code was in place when the building received its certificate of occupancy?

(2) Are there local amendments to that code? (see See the AHJ for this information)? .

(3) Were variances to the code granted during the design of the building based on performance-based analysis or some other justification? If so, design analysis reports should be available.

(4) What maintenance codes were in place during the lifetime of the suppression system?

(5) Does the insurance provider have additional suppression requirements that had an impact on the system design?

8.5.4.2 Design Analysis.

8.5.4.2.1 Fire Impact.

Understanding the design of non-water-based fire suppression systems is instrumental in determining what impact it may have had during a fire. Several important concepts in non-water-based fire suppression system design are highlighted in Sections 8.4.4.2.4 8.5.4.2.2 through 8.5.1 8.5.4.2.11 .

8.5.4.2.2 Hazard Protected.

Water-based Non water-based fire suppression systems are generally designed to protect against a certain level of hazard. The extent of the hazard that is being protected can extend from a localized area (i.e., “local area application”) or the volume of a compartment or compartments (i.e., “total flooding application”). The level of hazard will determine the total amount of agent required, needed; the application rate of the agent, ; the time interval required from delivery of the agent, and the time to sustain the presence of the agent, agent application rate, or agent concentration. More energy-efficient deep fat fryers and changes in cooking oils necessitated the movement from dry chemical to wet chemical agents in cooking applications.

8.5.4.2.3 Placement.

The position of distribution nozzles will greatly impact its the ability to provide water agent that can penetrate to the seat of a fire. NFPA's *National Fire Codes* provides standards and guidelines for detailed and specific requirements and recommendations for spacing and placement of distribution nozzles. In practice, several placement issues arise during or after installation that can have a negatively impact on the effectiveness of anon-water-based suppression system. One example is the relocation of cooking equipment in a commercial cooking installation. Another might be a carbon dioxide system nozzle that has been knocked out of position during maintenance of a printing press.

8.5.4.2.4 Installation.

Installation analysis of non-water-based fire suppression systems should be conducted by an engineer or other design professional that is familiar with the requirements of the applicable codes, as well as with any variances that may be in place for that design.

8.5.4.2.5 System Performance.

System performance is analyzed in much the same way as system installation. Several subcategories of system performance can be helpful in providing insight into the analysis of a specific fire or explosion event. System performance may be affected by ancillary systems, such as the shutting down of an air handling system in a room protected by a total flooding system.

8.5.4.2.6 Inspection, Testing & , and Maintenance.

Routine inspection, testing, and maintenance are important to the successful operation of non-water-based fire suppression systems. Local building codes contain requirements for inspection, testing, and maintenance and should be referenced during a system analysis. Testing Inspection, testing, and maintenance records should be maintained by the company that has performed them; data pertinent to these inspections should be provided on tags located near the main system valves.

8.5.4.2.7 Origin and Cause.

A number of useful data points relevant to the testing of hypotheses associated with the origin and cause of a fire that can be obtained through analysis of the activation or non-activation nonactivation of a non-water-based fire suppression system.

8.5.4.2.8 Timelines.

Non-water-based fire suppression systems can be activated by a connection to a fire alarm system. These systems may provide alarm times to a central monitoring service, or at least to the hard drive of a local alarm panel. Minimally, non-water- based At a minimum, a non-water-based fire suppression system would provide an alarm upon start of agent delivery. Other timeline information may also be available such as time tamper alarms that indicate what time valves were opened/closed (via tamper alarms) or other supervisory/trouble signals specific to that system. An effort should be made to synchronize any alarm system time data with and other investigative time data with a common clock.

8.5.4.2.9* Estimation of Fire Size.

Methods are available for estimating the size of a fire at the time of the first sprinkler activation.

8.5.4.2.10 Impact on Human Behavior.

The presence of automatic fire suppression systems, if known, may affect behavior. The effect may be positive or negative. A positive effect is that the increased margin of safety of such systems provides occupants of the involved structure more time to respond appropriately to the hazards presented by the incident. An example of a negative effect is possible decreased visibility caused by the discharge of the suppression agent, which may impede egress. Additionally In addition , the toxic effects of agents on humans can be an issue associated with the exposure of occupants to non-water-based suppression agents.

8.5.4.2.11* Fire Modeling.

A variety of computer models are available that may be used to calculate the activation time of a non-water-based fire suppression system and in some cases its potential impact on fire development. Regardless of which model is used, engineering guidelines for substantiating a fire model for a given application should be employed.

8.5 Documentation of Fire Protection Systems.

8.5.1 Design Documentation.

Design documentation regarding the particular fire protection system or component of interest to the investigator should be obtained. The number of design documents and the location of those documents may vary according to the specific type of system or component. Design documents are often modified from the time the project is conceived until it is built or installed. Obtain as many of the versions as possible. Design documents may be in the possession of the designer, manufacturer, certifying agency, installer, building owner or occupant, or AHJ.

8.5.2 Permit History.

If the design and/or installation of the system or component required a permit by the AHJ, the original permit file in the possession of the AHJ should be examined by the investigator and copied if necessary. The permit file may contain design drawings, modifications demanded by the AHJ, notices of deficiencies and inspection reports. If a permit was required by the AHJ but none was obtained, it should be noted.

8.5.3 Invoices and Contracts.

Draft contracts, final contracts, revised contracts, invoices for services and materials should be obtained. These documents may be in the possession of the parties to the contract, product seller, service provider, or installer.

8.5.4 Installation Documentation.

Upon completion of the project, “as built” plans may have been provided to the owner of the building. Depending upon the system, the furnishing of the “as built” drawings may be required per the standard, code, or AHJ. It is important to compare the “as built” plans with the actual installation as they may not conform. Discrepancies between the “as built” plans and the actual installation should be noted.

~~**8.5.5** Inspection and Maintenance Records.~~

~~Some fire protection systems required periodic inspection and maintenance. Codes, standards and the AHJ may require the periodic inspection and maintenance of systems and that such inspections and maintenance be documented. The inspection and maintenance documents may be found in the possession of the building owner or entity responsible for the building, the entity that serviced and/or inspected the system and the AHJ.~~

~~**8.5.6** Product Literature.~~

~~Information about the product generated by the manufacturer of the system or component part should be obtained. The literature may be in the possession of the system owner, product distributor, seller or available directly from the manufacturer. Product literature is often available on distributor and manufacturer websites. Product literature may have changed from the time the product was purchased or installed and the date of the investigation. Even if the original literature is available to the investigator, current literature on the product should be obtained to determine if any significant changes in the product or the literature have been made by the manufacturer. These changes may include design changes that impact the investigation and warnings that were not present in the original documentation. Some products, in order to meet the requirements of the AHJ, must be listed by a certifying agency such as Underwriters Laboratories (UL). The certifying agency will maintain a file on its testing of the product and possibly its inspection of the production facility.~~

~~**8.5.7** Alarm/Activation History.~~

~~Alarm systems may be monitored, sending data, in addition to alarm activation information, to a central monitoring station. The alarm monitoring company should be alerted as soon as possible to preserve all data recorded on its system. Some alarm panels retain data on the panel that is not transmitted to the central monitoring station. The data resident to the panel may be lost if the panel losses electrical power. The alarm system may have battery back-up power but once the battery losses its charge, the data may be lost. Care should be taken to preserve the panel and its source of power. The assistance of a qualified alarm expert should be considered before the data is lost or the panel is removed or manipulated.~~

8.6 Spoliation Issues.

Care should be taken to preserve all evidence and documents related to the fire protection systems ~~that come into the investigator's possession, particularly original documents~~ . ~~Even if only a copy is available, it may turn out to be the best evidence of that document and carry the same evidentiary weight as an original. Drawings are often oversized and are folded to fit into brief cases, folders and filing cabinets. Care should be taken to preserve paper documents with minimum folds and they should be stored in appropriate containers in safe environments. Documents provided to the investigator should be inventoried, a receipt given to the provider, and when necessary, a chain of custody maintained. Alarm panels should not be touched by untrained persons because data lost on those panels may not be recoverable.~~ Because understanding many of these systems requires special expertise, only those with appropriate knowledge and equipment should handle these systems and related evidence to avoid potential spoliation *(see 12.3.5)*. The loss or alteration of an item may have a significant consequence on the investigation and any litigation that may ensue.

Supplemental Information

File Name	Description
Staff_only_FR_33_Fig_8.3.2.1.tif	New figure 8.3.2.1 jpeg file.
Staff_only_FR_33_Chap_8.docx	Chapter 8 and Associated Annex A rewrite.

Submitter Information Verification

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Submittal Date: Fri May 15 13:55:05 EDT 2015

Committee Statement

Committee Statement: The committee has reorganized, clarified, and added images and photographs to Chapter 8 to improve the content.

[Staff Note: Section 8.3.4.5 Testing and Maintenance Analysis of the proposed Chapter 8 (First Revision No. 33) did not contain any text and has been marked as (Reserved). The committee can still consider it at the Second Draft Meeting.]

Response Message:

Public Input No. 106-NFPA 921-2014 [Section No. 8.3.4.2.1]
Public Input No. 68-NFPA 921-2014 [Section No. 8.3.4.2.2]
Public Input No. 84-NFPA 921-2014 [Section No. 8.3.4.2.2]
Public Input No. 155-NFPA 921-2014 [Section No. 8.2.4.4]
Public Input No. 44-NFPA 921-2014 [Section No. 8.5]
Public Input No. 86-NFPA 921-2014 [Section No. 8.3.4.3.4.7]
Public Input No. 103-NFPA 921-2014 [Section No. 8.3.3.1.1]
Public Input No. 60-NFPA 921-2014 [Section No. 8.3.4.3.4.5]
Public Input No. 61-NFPA 921-2014 [New Section after 8.3.2.4.2]
Public Input No. 83-NFPA 921-2014 [Section No. 8.3.2.1]
Public Input No. 121-NFPA 921-2014 [Section No. 8.3.3.4.1]
Public Input No. 82-NFPA 921-2014 [Section No. 8.4.4.1]
Public Input No. 120-NFPA 921-2014 [Section No. 8.3.3.4.1]
Public Input No. 85-NFPA 921-2014 [Section No. 8.3.4.3.4.10]
Public Input No. 67-NFPA 921-2014 [Section No. 8.3.4.3.1]
Public Input No. 69-NFPA 921-2014 [Section No. 8.3.2.1]
Public Input No. 74-NFPA 921-2014 [Section No. 8.6]
Public Input No. 75-NFPA 921-2014 [Section No. 8.4.4.2.9]
Public Input No. 76-NFPA 921-2014 [New Section after 8.4.4.2.3]
Public Input No. 77-NFPA 921-2014 [Section No. 8.4.4.2.6]
Public Input No. 119-NFPA 921-2014 [Section No. 8.3.3.4.1]
Public Input No. 64-NFPA 921-2014 [New Section after 8.3.1.2.2.5]
Public Input No. 122-NFPA 921-2014 [Section No. 8.3.3.4.1]
Public Input No. 79-NFPA 921-2014 [Section No. 8.5.2]
Public Input No. 80-NFPA 921-2014 [Section No. 8.4.4.2.8]
Public Input No. 65-NFPA 921-2014 [New Section after 8.3.4.3.5]
Public Input No. 157-NFPA 921-2014 [Section No. 8.2.2.4.2]
Public Input No. 158-NFPA 921-2014 [Section No. 8.2.2.4.3]
Public Input No. 159-NFPA 921-2014 [Section No. 8.2.4.5.2]

First Revision No. 36-NFPA 921-2015 [Section No. 9.6.3.4]

9.6.3.4 Ground Fault Circuit Interrupter (GFCI).

In newer installations, a GFCI is required for specific circuits, such as those serving bathrooms, kitchens, and outside receptacles. ~~Such interrupters often have a button labeled "push to test." This breaker houses a GFCI. It trips with a slight ground fault of about 5 milliamperes to give better protection for persons against electric shock at any level of amperage in the circuit. In addition, the breaker operates with overcurrents as an ordinary circuit breaker. The GFCI circuits are~~ All GFCIs are required to have a built-in test function for periodic testing. GFCIs are required to trip when an imbalance of 4–6 ma is detected. This level of current is deemed appropriate to avoid the inability to "let-go" of a live circuit. The GFCI is intended for bathrooms, patios, kitchens, or other locations where a person might be electrically grounded while near or using electrical appliances.

9.6.3.4.1 Ground Fault Circuit Interrupter (GFCI).

GFCIs can be found in the following configurations:

(1) *Portable GFCI.* GFCI not connected to the buildings electrical distribution panel and intended to provide GFCI protection — ground fault only, not overcurrent — for those instances where a GFCI is required but not provided within a building.

(2) *Receptacle type.* Electrical current is supplied by an electrical distribution panel to the GFCI. The GFCI provides ground fault protection – not overcurrent protection — at that location and all duplex outlets located downstream of the GFCI receptacle.

(3) *Circuit breaker–type GFCIs located within the distribution panel.* This type of GFCI provides ground fault and overcurrent protection to devices downstream from the panel.

Submitter Information Verification

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Submittal Date: Wed May 27 12:04:00 EDT 2015

Committee Statement

Committee Statement: The Committee has revised the wording of this section to more accurately describe the operation of GFCI's.

Response Message:

Public Input No. 36-NFPA 921-2014 [Section No. 9.6.3.4]

First Revision No. 37-NFPA 921-2015 [Section No. 9.6.3.5]

9.6.3.5 Arc Fault Circuit Interrupter (AFCI).

AFCIs are designed to ~~protect against~~ mitigate fires caused by arcing faults in home electrical wiring. The AFCI circuitry continuously monitors current flow. AFCIs use special circuitry to discriminate between normal and unwanted arcing conditions. Once an unwanted arcing condition is detected, the control circuitry in the AFCI opens the internal contacts, thus de-energizing the circuit and reducing the potential for a fire to occur. An AFCI should not trip during normal arcing conditions, which can occur when a switch is opened or a plug is pulled from a receptacle. Depending upon when the device was installed, *NFPA 70*~~,~~ ~~*National Electrical Code*~~ ~~, requires that bedroom circuits be protected by AFCI circuit breakers~~ may have required that a branch circuit supplying outlets or devices in kitchens, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas be protected by an AFCI .

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Committee Statement

Committee Statement: The proposed revision reflects the wording in the 2014 edition of NFPA 70 at paragraph 210.12(B),and the specific limitation of mitigation specified in UL1699, the standard for AFCI's.

Response Message:

Public Input No. 38-NFPA 921-2014 [Section No. 9.6.3.5]

First Revision No. 41-NFPA 921-2015 [Section No. 9.9.4.2.2]

9.9.4.2.2

Lightning can send ~~extremely~~ high voltage and current surges into an electrical installation. Because the voltages and currents from lightning strikes are so high, arcs can jump at many places, cause mechanical damage, and ignite many kinds of combustibles. *(See 9.12.8.)*

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Submittal Date: Thu May 28 11:36:09 EDT 2015

Committee Statement

Committee Statement: Lightning events most often induce or inject current pulses into electrical installations, generating overvoltage and overcurrent threats. CIGRE Technical Bulletin 549 identifies the source of the most damaging lightning effects as the lightning current. Current surges are being added to voltage surges in the list of lightning threats that cause damage to electrical circuits and result in fires.

Response Message:

Public Input No. 321-NFPA 921-2015 [Section No. 9.9.4.2.2]

First Revision No. 38-NFPA 921-2015 [New Section after 9.10.4]

9.10.4.1* Overheating in Duplex Receptacles

Overheating of poor electrical connections in duplex receptacles can lead to glowing connections *[see Figure 9.10.4(d)]* . Persistence of glowing connections can produce distinct evidence including melted copper conductors around steel screw terminals *[see Figure 9.10.4.1(a)]* , severed copper conductors at or near the screw head *[see Figure 9.10.4.1(b)]* , and enlarged screw heads due to severe corrosion *[see Figure 9.10.4.1(c)]* . These types of evidence are unique in appearance compared to melting and arcing events from external fire exposure. Poor connections may also exist at the point where the male plug blade contacts the internal receiver, or bus, of the duplex receptacle. The investigator should also find evidence of a loose or poor electrical connection.

Figure 9.10.4.1(a) Melted Copper Conductor Around Steel Screw Terminal Resulting from Glowing Connection.

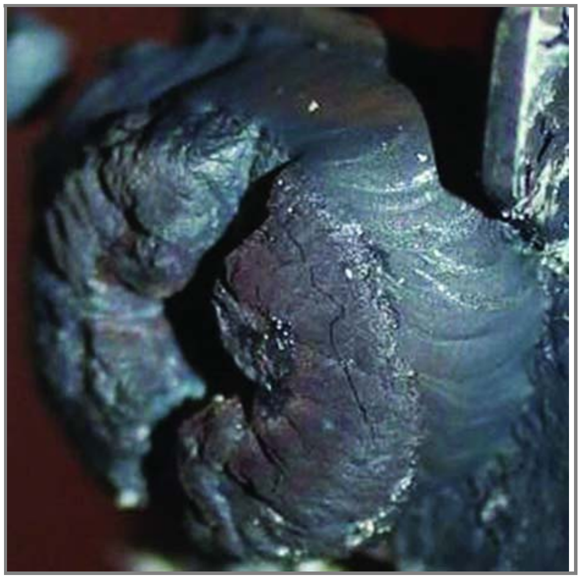

Figure 9.10.4.1(b) Severed Copper Conductor Near Screw Terminal Resulting from Glowing Connection.

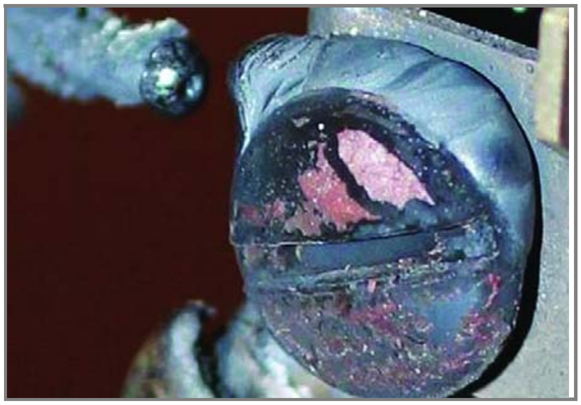

Figure 9.10.4.1(c) Enlarged Screw Head on Duplex Outlet Resulting from Severe Corrosion and Glowing Connection.

Supplemental Information

File Name	Description
FR_38_A.9.10.4.1.docx	New annex A.9.10.4.1.
Staff_only_FR_38_Fig_9.10.4.1_a_.jpg	New figure 9.10.4.1(a).
Staff_only_FR_38_Fig_9.10.4.1_b_.jpg	New figure 9.10.4.1(b).
Staff_only_FR_38_Fig_9.10.4.1_c_.jpg	New figure 9.10.4.1(c).

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Committee Statement

Committee Statement: The committee has added wording to clarify overheating conditions in duplex receptacles.
Response Message:
Public Input No. 313-NFPA 921-2015 [New Section after 9.10.4]

A.9.10.4.1 For more information see:

Benfer, M., Gottuk, D., Development and Analysis of Electrical Receptacle Fires, NIJ-2010-DN-BX-K218, Baltimore, MD, 2013.

First Revision No. 39-NFPA 921-2015 [New Section after 9.10.6]

9.10.7* Insulation Damage.

Electrical insulation is rated to withstand a certain maximum operating voltage. If this voltage is exceeded, the insulation may break down (i.e., an electric discharge could pass through the solid material, permanently damaging it and causing a temporary fault path during the event). Insulation materials are normally specified to resist voltages above the intended operating voltage, including a safety margin. However, mechanical damage to the insulation is likely to reduce the dielectric breakdown strength. If the reduction is so large that the breakdown strength falls below the operating voltage, then a dielectric breakdown can be expected. Damaged insulation may have a breakdown strength above the normal operating voltage, yet below the voltage of some surges that might occur. In such cases, breakdown will occur only when a surge of sufficient magnitude is experienced.

9.10.7.1* Hammer Mis-Hits.

If a hammer is used to install electric cables, a mis-hit may occur whereby the installer strikes the cable instead of the staple with the hammer. This can result in difficult-to-see damage to the wire insulation. For some mis-hits, the dielectric strength of the damaged cable can become lower than expected surge voltages. This can create arcs and a potential fire when a high-voltage surge occurs, which could happen long after the original installation.

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Submittal Date: Wed May 27 15:45:04 EDT 2015

Committee Statement

Committee Statement: An explanation is added for surge voltages and the potential for fires to occur when insulation is damaged. This is especially true for damage due to mis-hits when using hammers to install staples on NM cables. The proposed wording explains the phenomenon and the asterisk material provides the appropriate references.

Response Message:

Public Input No. 150-NFPA 921-2014 [New Section after 9.10.6.4]

First Revision No. 42-NFPA 921-2015 [Section No. 9.11 [Excluding any Sub-Sections]]

Melted electrical conductors can be examined to determine if the damage is evidence of electrical arcing ~~or melting by fire~~ , melting by fire, or eutectic melting. Visual examination can provide reliable identification of damage from electrical arcing and melting by fire for most conductors. However, more advanced examination techniques including SEM/EDS examinations, X-ray, CT scanning (i.e., X-ray computed tomography), cross-sectioning and polishing, or other metallurgical methods could assist in discerning between damage by electrical arcing and melting by fire. Paragraph 9.11.1.1 and 9.11.2 identify characteristic traits commonly exhibited in arc-damaged conductors and fire-melted conductors, respectively. Using multiple characteristic traits and contextual information (e.g., damage to other components) when identifying damaged conductors provides greater confidence in the evaluation of that damage .

Supplemental Information

File Name	Description
FR_42_A.9.11.docx	Revised Annex A.9.11.

Submitter Information Verification

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Committee Statement

Committee Statement: This language adds additional guidance when differentiating between arcing and melting.

Response Message:

Public Input No. 252-NFPA 921-2015 [Section No. 9.11 [Excluding any Sub-Sections]]
Public Input No. 314-NFPA 921-2015 [Section No. 9.11 [Excluding any Sub-Sections]]

Annex A Explanatory Material

Annex A is not a part of the recommendations of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.9.11 For information on characteristics of arc bead and melt globules, see the following references:

Buc, E. C., Reiter, D., Battley, J., Sing, T. B., and Sing, T. M., "Method to Characterize Damage to Conductors from Fire Scenes," *Proc. Fire & Materials 2013 Conf.*, pp. 657–665, Interscience Communications Ltd, London (2013).

Benfer, M., Gottuk, D., Development and Analysis of Electrical Receptacle Fires, NIJ-2010-DN-BX-K218,Baltimore, MD, 2013.

Carey, N. J., Developing a Reliable Systematic Analysis for Arc Fault Mapping (Ph.D. dissertation), Univ. Strathclyde, Strathclyde, United Kingdom (2009).

Delplace, M., and Vos, E., "Electric Short Circuits Help the Investigator Determine Where the Fire Started," *Fire Technology* 19, 185–191 (1983).

Ettling, B. V., "Electrical Wiring in Building Fires," *Fire Technology* 14, 317–325 (1978).

Lewis, K. H., and Templeton, B., "Morphological Variation in Copper Arcs during Post-Arc Fire Heating," *ISFI 2008—Proc. 3rd Intl. Symp. on Fire Investigation Science & Technology*, pp. 183–195, Natl. Assn. of Fire Investigators, Sarasota, FL (2008).

Murray, I., and Ajersch, F., "New Metallurgical Techniques Applied to Fire Investigation," *Fire & Materials 2009*, pp. 857–869, Interscience Communications Ltd., London (2009).

Twibell, J. D., "Electricity and Fire," *Fire Investigation*, pp. 61–104, N. N. Daeid, ed., CRC Press, Boca Raton, FL (2004).

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First Revision No. 43-NFPA 921-2015 [Section No. 9.11.2]

9.11.2 Melting Caused by Fire.

In contrast to melting caused by an arc, when conductors are melted by fire, the damage is spread over a larger area without a distinct line of demarcation between the melted and unmelted regions *(see 9.10.6.2)*. Conductors melted by fire may exhibit irregular or rounded globules, or smooth or rough tapered ends. The following traits are commonly exhibited for ~~arc damaged~~ fire-melted conductors:

(1) Visible effects of gravity on the artifact

(2) Extended area of damage without a sharp demarcation from undamaged material

(3) Gradual necking of the conductor ~~(~~ — assuming this is not due to a mechanical break~~)~~

(4) Low internal porosity when viewed in a cross-section

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Committee Statement

Committee Statement: The committee recognizes this as an editorial change.

Response Message:

Public Input No. 316-NFPA 921-2015 [Section No. 9.11.2]

Public Input No. 164-NFPA 921-2014 [Section No. 9.11.2]

First Revision No. 44-NFPA 921-2015 [Section No. 9.11.7.5.2]

9.11.7.5.2

~~When~~ Where multiple arcs are found on a single circuit and there is a sever arc closer to the supply ~~then~~ than other arcs, then the downstream arcs ~~necessarily~~ occurred no later than the sever arc.

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Committee Statement

Committee Statement: This changes is editorial and corrects a grammatical error.
Response Message:
Public Input No. 171-NFPA 921-2014 [Section No. 9.11.7.5.2]

First Revision No. 45-NFPA 921-2015 [Section No. 9.12.8.2]

9.12.8.2 Lightning ~~Bolt~~ Characteristics.

Typical~~ly~~ lightning ~~bolts~~ channels have a core of energy plasma 12.7 mm to 19 mm (½ in. to ¾ in.) in diameter, surrounded by a 102 mm (4 in.) thick channel of superheated ionized air. Lightning ~~bolts average 24,000~~ return stroke currents average between 30,000 A and 45,000 A depending upon location, but can exceed 200,000 A~~, and potentials~~ . Potentials can range up to 15,000,000 V.

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Committee Statement

Committee Statement: The committee has revised this paragraph to be consistent with NFPA 780.
Response Message:
Public Input No. 325-NFPA 921-2015 [Section No. 9.12.8.2]

First Revision No. 46-NFPA 921-2015 [Section No. 9.12.8.3.1]

9.12.8.3.1

Lightning ~~tends to strike the tallest object on the ground in the path of its discharge. Lightning enters structures in four ways~~ may strike any object that generates a successful upward-going streamer connecting with the dart leader generated from the cloud. This may be the tallest object but could also be the perimeter of a roof that is not the tallest item on the structure. Lightning threats to a structure consist of the following :

(1) ~~By striking a metallic object like a TV antenna, a cupola, or an air-conditioning unit extending up and out from the building roof~~ A direct strike to the structure or an item attached to the structure, such as a TV antenna, air-conditioning unit, and so forth, extending up and out from the building roof)

(2) ~~By directly striking the structure~~ A strike near a structure that couples energy onto internal conductors

(3) ~~By hitting a nearby tree or other tall structure and moving horizontally to the building~~ A direct strike to incoming conductors connected to the structure

(4) ~~By striking nearby overhead conductors and by being conducted into buildings along the normal power lines~~ A strike near overhead conductors that can couple lightning currents onto conductors connected to the structure

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Committee Statement

Committee Statement: The committee has revised this paragraph to be consistent with NFPA 780.
Response Message:

Public Input No. 326-NFPA 921-2015 [Section No. 9.12.8.3.1]

First Revision No. 47-NFPA 921-2015 [Section No. 9.12.8.4]

9.12.8.4 Lightning Damage.

Damage by lightning is caused by two characteristic properties: ~~first, the extremely~~ high ~~electrical potentials~~ currents and energy in a lightning ~~stroke~~ strike ~~;~~ and ~~second, the~~ extremely high heat energy and temperatures generated ~~by~~ in the channel by the electrical discharge. *[See 9.12.8.4(A) through (D).]* ~~are examples of these effects.~~

(A)

A tree ~~may~~ can be shattered by ~~the explosive action of the lightning stroke striking the tree and the heat immediately~~ lightning current conducted deep into the tree's heartwood with the heat vaporizing the moisture in the tree into steam~~, causing~~ — with explosive effects.

(B)

Copper conductors not designed to carry the thousands of amperes of a lightning ~~stroke~~ strike may be melted, severed, or completely vaporized by the overcurrent effect of a lightning discharge. ~~It is also characteristic for electrical conductors that have experienced significant overcurrents to become severed and disjointed at numerous locations along their length, due to the extremely powerful magnetic fields generated by such overcurrents.~~ Lightning currents may also generate overvoltages that trigger power system overcurrents sufficient to sever conductors in one or more locations. Copper and aluminum conductors properly sized and routed in accordance with NFPA 780 will not be damaged by a lightning impulse current up to 200,000 A.

(C)

~~When~~ Where lightning strikes a steel-reinforced concrete building, the ~~electricity~~ current may follow the steel reinforcing rods as the least resistive ~~conductive~~ path. The high energy ~~and high temperatur~~ e may destroy the surrounding concrete with explosive force~~s~~ to get to the reinforcing steel .

(D)

Lightning can also cause fires by damaging fuel gas systems. Fuel gas appliance connectors have been known to have their flared ends damaged by electrical currents induced by lightning and other forms of electrical discharge. ~~When~~ Where gas lines are damaged, fuel gas can leak, and the same arcing that caused the gas line to fail may also cause ignition of the fuel gas.

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Committee Statement

Committee Statement: The committee has revised this paragraph to be consistent with NFPA 780.

Response Message:

Public Input No. 324-NFPA 921-2015 [Section No. 9.12.8.4]

First Revision No. 131-NFPA 921-2015 [Section No. 10.9.4.8.1]

10.9.4.8.1

The leaks created by such strain may develop at junctions far removed from the actual point of physical contact~~. For example~~ (e.g. , if an automobile strikes a gas meter assembly, the strain on the underground piping of the system may cause a leak at ~~a distant,~~ an underground pipe union many feet away~~. The~~ ; or, the movement of a gas range away from a wall may strain the gas piping system and cause a leak at the junction of the flexible tubing and the rigid main gas line or at a junction within the range itself. *(See Figure 10.9.4.8.1 .)*

Figure 10.9.4.8.1 Cracked Gas Fitting May Cause Gas Leak or May Be the Result of the Event.

Supplemental Information

File Name	Description
Staff_only_FR_131_Fig_10.9.4.8.1.JPG	1. New figure 10.9.4.8.1.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Submittal Date: Mon Jun 01 11:29:55 EDT 2015

Committee Statement

Committee Statement: Inclusion of color image as an example.
Response Message:

First Revision No. 48-NFPA 921-2015 [Section No. 11.3.1.2]

11.3.1.2 Cognitive Comprehension Limitations.

Cognitive comprehension limitations, which may affect an individual's ability to recognize and react appropriately to the hazards presented by a fire or an explosion incident, include age (as it relates to and mental comprehension) level , level of rest, alcohol use, drug use (legal or illegal) drug use , developmental disabilities, mental illness, and inhalation of smoke and toxic gases. These cognitive limitations are more likely to affect an individual's ability to accurately assess the hazards presented by a fire or explosion. Often, such limitations account for delayed or inappropriate responses to such hazards. Children may fail to recognize the a hazard and choose an inappropriate response, such as hiding or seeking a parent. Many times a victim may be affected by multiple agents (e.g., alcohol ingested in a pre-ignition period and carbon monoxide in a post-ignition period). Investigators should carefully assess all possibilities before making assumptions. Behavior that is often determined to be inappropriate may be due to confusion caused by toxic gases.

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Committee Statement

Committee Statement: This provides useful additional information.
Response Message:
Public Input No. 217-NFPA 921-2014 [Section No. 11.3.1.2]

First Revision No. 49-NFPA 921-2015 [Section No. 14.5.4.3]

14.5.4.3 ~~Department of Defense~~ Military Branches .

The Department of Defense (DOD) oversees all ~~of the~~ military branches of the armed services, including the Army, the Navy, the Marine Corps, and the Air Force~~, and the Coast Guard~~ . The Coast Guard is under the control of the Department of Homeland Security, except in time of war where the Coast Guard would then fall under the Department of the Navy. Each branch of ~~these branches of~~ the military maintains public records regarding its activities and personnel. Each ~~of these~~ branches has offices that conduct criminal investigations within its specific branch of armed service.

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Committee Statement

Committee Statement: This change addresses the current status of the coast guard.

Response Message:

Public Input No. 30-NFPA 921-2014 [Section No. 14.5.4.3]

First Revision No. 50-NFPA 921-2015 [Section No. 14.6.6.2]

14.6.6.2

In addition to an annual seminar, there are also regional seminars focusing on fire investigator training and education. ~~The Association~~ IAAI also publishes ~~the~~ *Fire and Arson Investigator*, a quarterly ~~magazine~~ journal ~~. The IAAI~~ , and offers a ~~written examination for investigators meeting IAAI minimum qualifications to become an IAAI–certified fire investigator (CFI)~~ number of certifications and professional designations, including the pro board–accredited IAAI-certified fire investigator program based on NFPA 1033 , the IAAI fire investigation technician program based on portions of NFPA 1033 , IAAI certified instructor based on NFPA 1041 , and the IAAI evidence collection technician based on NFPA 1033 and relevant ANSI standards . ~~Additionally~~ In addition , the IAAI offers a distance learning platform available at www.cfitrainer.net.

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Committee Statement

Committee Statement: The new text appropriately defines the professional programs and designations offered by the IAAI.
Response Message:

Public Input No. 278-NFPA 921-2015 [Section No. 14.6.6.2]

First Revision No. 51-NFPA 921-2015 [Section No. 14.6.11]

14.6.11 Insurance Industry.

14.6.11.1

The insurance industry ~~certainly~~ has an interest in the results of most fire and explosion incidents. ~~The insurance industry~~ Most insurance companies have established special investigation units (SIUs) that may be tasked with investigating fires and explosions involving property they insure. Trained and experienced SIU or claims personnel can provide the fire investigator with ~~a diverse amount of~~ information concerning the structure or vehicle involved and the person(s) who insured them. *(See 12.5.6.5.)*

14.6.11.2

The insurance industry ~~also funds~~ funds or contributes to property loss or claims databases like the ~~Property Insurance Loss Register~~ property insurance loss register (PILR) and ISO ClaimSearch , which ~~receives~~ collect data from reports of all types of property losses, ~~through~~ including fire, ~~burglaries, and thefts. It is a computerized index of the insurance companies that paid the claims, the person to whom the claim was paid~~ theft, and burglary. Claims recorded into the databases contain relevant information about the claim including the insurance company involved , the type of claim reported , ~~and the like. It can serve as a valuable source of information to the fire investigator~~ the persons involved in the claim, and the amount paid on the claim .

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Committee Statement

Committee Statement: The changes provide updated and expanded sources of information.
Response Message:

Public Input No. 186-NFPA 921-2014 [Section No. 14.6.11]

First Revision No. 52-NFPA 921-2015 [Section No. 15.2.8.2]

15.2.8.2

The investigator, ~~particularly~~ the ~~private sector~~ private-sector investigator in particular , ~~may~~ should recommend to the client that they need to ~~make a reasonable effort to~~ notify all ~~parties, identifiable at that time,~~ identifiable interested parties who may have a legal interest in the investigation of the inspection and give them the opportunity to participate or witness and record such activities . *(See Section 12.3 and ASTM E-860, Standard Practice for Examining and Preparing Items that Are or May Become Involved in Criminal or Civil Litigation .)*

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Submittal Date: Thu May 28 14:35:42 EDT 2015

Committee Statement

Committee Statement: The new language is consistent with the ASTM standard.
Response Message:

Public Input No. 124-NFPA 921-2014 [Section No. 15.2.8.2]

First Revision No. 56-NFPA 921-2015 [Section No. 16.1]

16.1* Introduction.

16.1.1

The goal in documenting any fire or explosion investigation is to accurately record make an accurate recording of the investigation through using media that will allow investigators to recall and communicate their observations at a later date. Common methods of accomplishing this goal include the use of photographs, videotapes video , diagrams, maps, overlays, tape audio recordings, laser surveys, digital and handwritten, notes, sketches, and reports.

16.1.2

Thorough and accurate documentation of the investigation is critical, because it is from this compilation of factual data that is necessary to support and verify investigative opinions and conclusions can be supported and verified . There are a number of resources to assist the investigator in documenting the investigation.

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Submittal Date: Thu May 28 16:25:29 EDT 2015

Committee Statement

Committee Statement: These two paragraphs are to revise the existing text in paragraphs 16.1.1 and 16.1.2 in the current document. The committee has made these revisions to clarify and enhance the text.

Response Message:

First Revision No. 57-NFPA 921-2015 [Section No. 16.2]

16.2 Photography.

16.2.1* General.

~~A visual documentation of the fire scene can be made using either still or video photography. Images can portray the scene better than words. They are the most efficient reminders of what the investigator saw while at the scene. Patterns and items may become evident that were overlooked at the time the photographs or videos were made. They can also substantiate reports and statements of the investigator.~~ The fire scene should be documented using still photography, which can be supplemented with video photography. Photographs are the most efficient and effective reminders of what the investigator saw while at the scene. Important items that were documented by photography may become more evident upon review of the photographs or videos. Photographs and video are necessary to substantiate the investigator's observations.

~~**16.2.1.1**~~

~~For fire scene and investigation-related photography, color images are recommended.~~

16.2.1.1* Photography and Videography.

Investigators should be familiar with the photography and videography equipment and technology ~~they are using~~ . ~~Taking a basic photography or video course through a vocational school, camera club, or camera store would be most helpful in getting the photographer familiar with the equipment.~~ Instruction and training in photography and videography can help familiarize the investigator with different photographic techniques and the capabilities of the equipment and technology.

16.2.1.2 Image Authentication.

With digital images, as with film photographs, the tests of "a true and accurate representation" and "relevance to the testimony" must be met.

16.2.1.2.1

Digital images can be enhanced using ~~readily~~ available computer technology. Routine image enhancement ~~of the image~~ can be used to correct brightness, color, and contrast. These enhancements were ~~frequently carried out automatically~~ made by developers when film was the medium of choice. If an image has been enhanced, it is incumbent upon the investigator to preserve the original image and to document the extent to which the image was enhanced, should enhancement become an issue.

16.2.1.2.2*

Steps should be taken to preserve the original image and establish a methodology to allow authentication. A~~n agency~~ procedure should be established for the secure storage of images~~,~~ (e.g., ~~such as~~ placement on an appropriate storage medium that will not allow them to be altered, or the utilization of a computer software program that does not allow the original image to be altered and saved using the original file name~~,~~). ~~or other programs that may be developed in the future.~~ Current imaging technology can track alterations of the original image and record any changes in the image's metadata (i.e., the image's digital file). The original photographs and the metadata should be secured and maintained.

~~**16.2.1.2**~~

~~As many photographs should be taken as are necessary to document and record the fire scene adequately. It is far preferable to err on the side of taking too many photographs rather than too few.~~

~~**16.2.1.2**~~

~~The exclusive use of video is not recommended. Video is more effective when used in conjunction with still photographs.~~

16.2.2 Timing.

Taking photographs or video during the fire or as soon as possible after a fire is important when documenting the fire scene, as the scene may become altered, disturbed, or even destroyed. Other situations ~~when~~ where time is important include the following:

(1) The building is in danger of imminent collapse or the structure must be demolished for safety reasons.

(2) Hazardous materials or processes may create an imminent environmental hazard that needs immediate attention.

(3) Evidence can be altered during overhaul and investigation. Evidence should be documented when discovered as layers of debris are removed. Documenting the layers can also assist in understanding the course of the fire.

16.2.3 Basics.

16.2.3.1 Types of Cameras.

Digital equipment for stills and video has replaced film equipment as the technology of choice for scene documentation. There is a multitude are many types of digital cameras types available to the investigator, from small, inexpensive point-and-shoot models to elaborate digital single lens reflex (dSLR) versions with that can utilize a wide range of supplemental lenses' and attachments. Most digital cameras offer a variety of automatic modes, which can be changed with manual adjustments for specific conditions (e.g., manual focus, macro mode, lighting).

16.2.3.1.1 Color Images.

For fire scene– and investigation-related photography, color images are recommended.

16.2.3.1.2 Resolution.

Resolution will affects the useable size of the an image taken. Lower A lower resolution would limits the size of the an image when for used as an exhibit at trial. Resolution is measured in pixels. The more pixels a camera has, the greater the detail it can capture and the larger the image that can be effectively used for demonstrative purposes.

16.2.3.1.3 Number of Photographs Taken.

As many photographs should be taken as are necessary to document and record the fire scene adequately. Photographs should be taken of fire effects and fire patterns, observations, artifacts, and other items that may be of evidentiary value. The importance of taking enough photographs cannot be over-stated. It is far preferable to err on the side of taking too many photographs rather than too few. The investigator should ensure that adequate photographic equipment is available prior to starting the investigation.

16.2.3.2 General.

The most fundamental aspect of photography that an investigator should comprehend is how a camera works. The easiest way to learn how a camera works is to compare the camera to the human eye.

16.2.3.2.2

One of the most important aspects to remember about fire investigation photography is light. The average fire scene consists of blackened subjects and blackened background, creating much less than ideal conditions for taking a photograph. As one can imagine, walking into a dark room causes the human eye to expand its pupil in order to gather more light; likewise, the camera requires similar operation. The person in a dark room normally turns on the light to enhance vision, just as a photographer uses a flash or floodlight to enhance the imitated vision of the camera.

16.2.3.2.1

Both the human eye and the camera project an inverted image on the light-sensitive surface—the charge coupled device (CCD) in the camera, and the retina in the eye. The amount of light admitted is regulated by the iris (eye) or diaphragm (camera). Additionally the camera shutter controls the time during which the light is admitted.

16.2.3.2 Types of Cameras.

There is a multitude of camera types available to the investigator, from small, inexpensive models to elaborate versions with a wide range of attachments.

16.2.3.2.1

Some cameras are fully automatic, giving some investigators a sense of comfort knowing that all they need to do is point and shoot. These cameras adjust the lens opening (f-stop), control the shutter speed, operate the flash, and focus the lens.

16.2.3.2.3

A digital camera having a resolution of at least 5 megapixels is recommended. Digital images can be immediately reviewed for quality, and a new image collected if necessary. Digital images can also be enlarged on site to ensure that sufficient detail is available.

16.2.3.3 Image Authentication.

With digital images, as with film photographs, the tests of "a true and accurate representation" and "relevance to the testimony" must be met.

16.2.3.3.1

Digital images can be enhanced using readily available computer technology. Routine enhancement of the image can be used to correct brightness, color and contrast. These enhancements were frequently carried out automatically by developers when film was the medium of choice. If an image has been enhanced, it is incumbent upon the investigator to preserve the original image and to document the extent to which the image was enhanced, should enhancement become an issue.

16.2.3.3.2*

Steps should be taken to preserve the original image and establish a methodology to allow authentication. An agency procedure should be established for the storage of images, such as placement on an appropriate storage medium that will not allow them to be altered, or the utilization of a computer software program that does not allow the original image to be altered and saved using the original file name, or other programs that may be developed in the future.

16.2.3.3 Lenses.

~~The camera lens is used to gather light and to focus the image on the camera's detector. Most of today's lenses are compound, meaning that multiple lenses are located in the same housing. The fire investigator needs a basic understanding of the lens function to obtain quality images. The convex surface of the lens collects the light and sends it to the back of the camera, where it is collected on the CCD. The aperture is an adjustable opening in the lens that controls the amount of light admitted. The adjustments of this opening are sectioned into measurements called f-stops. As the f-stop numbers get larger, the opening gets smaller, admitting less light. These f-stop numbers are listed on the movable ring of the adjustable lenses. Normally, the higher the f-stop that can be used, the better the depth of field of the image.~~

~~**16.2.3.3.1**~~

~~Focal lengths in lenses range from a normal lens (50 mm, which is most similar to the human eye) to the wide angle (15 mm or less) lenses, to telephoto and zoom lenses (typically 80 mm or greater, depending on the size of the CCD). The investigator needs to determine what focal lengths will be used regularly and become familiar with the abilities of each.~~

~~**16.2.3.3.2**~~

~~The area of clear definition or depth of field is the distance between the farthest and nearest objects that will be in focus at any given time. The depth of field depends on the distance to the object being photographed, the lens opening, and the focal length of the lens being used. The depth of field will also determine the quality of detail in the investigator's images. For a given f-stop, the shorter the focal length of the lens, the greater the depth of field. For a given focal length lens, a larger f-stop (smaller opening) will provide a greater depth of field. This is an important technique to master. These are the most common lens factors with which the fire investigator needs to be familiar. If a fixed-lens camera is used, the investigator need not be concerned with adjustments, because the manufacturer has preset the lens. A recommended lens is a medium range zoom, in the range of 20 mm to 80 mm (depending on the size of the CCD), providing a wide angle with a good depth of field and the ability to take close-ups.~~

~~**16.2.3.3** Filters.~~

~~The investigator should know that problems can occur with the use of colored filters. Unless the end results of colored filter use are known, it is recommended that they not be used. If colored filters are used, the investigator should take an image with a clear filter also. The clear filter can be used continually and is a good means of protecting the lens.~~

~~**16.2.3.2** Lighting.~~

~~The most usable light source known is the sun. No artificial light source can compare realistically in terms of color, definition, and clarity. At the beginning and end of the day, inside a structure or an enclosure, or on an overcast day, a substitute light source will most likely be needed. This light can be obtained from a floodlight or from a strobe or flash unit integrated with the camera. Because a burned area has poor reflective properties, artificial lighting using floodlights can be useful.~~

~~**16.2.3.4.1**~~

~~There are instances when the time period during which a photograph was taken will be important to an understanding of what the photograph depicts. In photographs of an identical subject, natural lighting conditions that exist at noon may result in a significantly different photographic image than natural lighting conditions that exist at dusk.~~

~~**16.2.3.4.1**~~

~~Flash units are necessary for the fire investigator's work. A flash unit that can be removed from the camera body so that it can be operated at an angle oblique to that of the lens view may be helpful. This practice is valuable in reducing the amount of reflection, obtaining a greater depth of field, and amplifying the texture of the heat- and flame-damaged surfaces.~~

~~**16.2.3.4.1**~~

~~Flash units are necessary for the fire investigator's work. A flash unit that can be removed from the camera body so that it can be operated at an angle oblique to that of the lens view may be helpful. This practice is valuable in reducing the amount of reflection, obtaining a greater depth of field, and amplifying the texture of the heat- and flame-damaged surfaces.~~

~~**16.2.3.4.1**~~

~~The use of multiple flash units and remote operating devices called slaves can illuminate large areas.~~

~~**16.2.3.2.1** Lenses.~~

~~The camera lens is used to gather light and to focus the image on the camera's detector . Most of today's lenses are compound, meaning that multiple lenses are located in the same housing. The fire investigator needs a basic understanding of the lens function to obtain quality images photographs. The convex surface of the lens collects the light and sends it to the back of the camera, where it is collected on the CCD. The lens aperture is an adjustable opening in the lens that controls the amount of light admitted. The adjustments of this opening are sectioned into measurements increments called f-stops. As the f-stop numbers get larger increase, the size of the opening gets smaller decreases, admitting less light. These f-stop numbers are listed on the movable ring of the adjustable lenses. Normally, the The higher the f-stop that can be used, the better the depth of field of the image. There is a trade-off between depth of field (f-stop) and adequate light (shutter speed). The photographer needs to balance the desire for more depth of field with the need for adequate light.~~

16.2.3.2.2 Focal Length.

Focal lengths in lenses range from a normal lens (50 mm, which is most similar to the human eye) to the wide angle (15 mm or less) lenses, to telephoto and zoom lenses (typically 80 mm or greater, depending on the size of the CCD). The investigator Digital cameras have variable or fixed focal length lenses that range from 20 mm to 1200 mm or greater. Some digital cameras are equipped with optical zoom (i.e., uses the lens), digital zoom (i.e., uses digital capture from lens image), or both. Macro lenses are useful for close-up photography. Investigators needs to should determine what the focal lengths they will be used regularly use most often and become familiar with the abilities of each and limitations of the equipment.

16.2.3.2.3 Depth of Field.

The area of clear definition, or depth of field, is the distance between the farthest and nearest objects that will be in focus at any given time. The depth of field depends on the distance to the object being photographed, the lens opening, and the focal length of the lens being used. The depth of field will also determine the quality of detail in the investigator's images. For a given f-stop, the shorter the focal length of the lens, the greater the depth of field. For a given focal length lens, a larger f-stop (i.e., smaller opening) will provide a greater depth of field. This is an important technique to master. These are the most common lens factors with which the fire investigator needs to be familiar. If a fixed-lens camera is used, the investigator need not be concerned with adjustments, because the manufacturer has preset the lens. A recommended lens is a medium range medium-range zoom, in the range of 20 mm to 80 mm (depending on the size of the CCD sensor) , providing a wide angle with a wide angle and a good depth of field and the ability to take close-ups.

16.2.3.2.4 Filters.

The investigator should know that problems can occur with the use of colored filters is problematic. Unless the end results of colored filter use are known, it is recommended that they not be used. If colored filters are used, the investigator should take an image with a clear filter also as well. The clear An ultra-violet (UV) filter can be used continually as it reduces haze, improves contrast, and is a good means of protecting the lens.

16.2.3.2.5 Shutter Speed.

A minimum amount of light is required for a good exposure. As the aperture is decreased (increased f-stop), the amount of light admitted per unit time decreases, so a longer shutter speed is required. Shutter speeds below 1/60 sec (60) require a tripod to avoid blurring of the image.

16.2.3.4.3

For close-up work, a ring flash will reduce glare and give adequate lighting for the subject matter. Multiple flash units can also be used to give a similar effect to the ring flash by placing them to flash at oblique angles. A ring flash may in some cases “flatten” the image. This can be avoided by using multiple flashes, or by using a standard flash angled downward.

16.2.3.4.3

The investigator should be sure that glare from a flash or floodlight does not distort the actual appearance of an object. For example, smoke stains could appear lighter or nonexistent. In addition, shadows created could be interpreted as burn patterns. Movie lights used with video cameras can cause the same problems as still camera flash units. Using bounce flash, light diffusers, or other techniques may alleviate this problem.

16.2.3.4.3

The investigator concerned with the potential outcome of a photograph can bracket the exposure. *Bracketing* is the process of taking the same subject matter at slightly different exposure settings to ensure at least one correct exposure.

16.2.3.5 Special Types of Photography.

Today's technology has produced some specialty types of photography. Infrared, laser, panoramic and microscopic photography can be used under controlled circumstances. An example is the ability of laser photography to document a latent fingerprint found on a body.

16.2.4 Understanding the Parts of a Camera.

16.2.4.1 Lenses.

The camera lens is used to gather light and to focus the image on the camera's detector . Most of today's lenses are compound, meaning that multiple lenses are located in the same housing. The fire investigator needs a basic understanding of the lens function to obtain quality images photographs . The convex surface of the lens collects the light and sends it to the back of the camera, where it is collected on the CCD. The lens aperture is an adjustable opening in the lens that controls the amount of light admitted. The adjustments of this opening are sectioned into measurements increments called f-stops. As the f-stop numbers get larger increase , the size of the opening gets smaller decreases , admitting less light. These f-stop numbers are listed on the movable ring of the adjustable lenses. Normally, the The higher the f-stop that can be used, the better the depth of field of the image. There is a trade-off between depth of field (f-stop) and adequate light (shutter speed). The photographer needs to balance the desire for more depth of field with the need for adequate light.

16.2.4.2 Focal Length.

~~Focal lengths in lenses range from a normal lens (50 mm, which is most similar to the human eye) to the wide angle (15 mm or less) lenses, to telephoto and zoom lenses (typically 80 mm or greater, depending on the size of the CCD). The investigator~~ Digital cameras have variable or fixed focal length lenses that range from 20 mm to 1200 mm or greater. Some digital cameras are equipped with optical zoom (i.e., uses the lens), digital zoom (i.e., uses digital capture from lens image), or both. Macro lenses are useful for close-up photography. Investigators ~~needs to~~ should determine ~~what~~ the focal lengths they will ~~be used regularly~~ use most often and become familiar with the abilities ~~of each~~ and limitations of the equipment .

16.2.4.3 Depth of Field.

The area of clear definition, or depth of field, is the distance between the farthest and nearest objects that will be in focus at any given time. The depth of field depends on the distance to the object being photographed, the lens opening, and the focal length of the lens being used. The depth of field will also determine the quality of detail in the investigator's images. For a given f-stop, the shorter the focal length of the lens, the greater the depth of field. For a given focal length lens, a larger f-stop (i.e., smaller opening) will provide a greater depth of field. ~~This is an important technique to master. These are the most common lens factors with which the fire investigator needs to be familiar.~~ If a fixed-lens camera is used, the investigator need not be concerned with adjustments, because the manufacturer has preset the lens. A recommended lens is a ~~medium range~~ medium-range zoom, ~~in the range of~~ 20 mm to 80 mm ~~(~~ depending on the size of the ~~CCD~~ sensor ~~)~~ , ~~providing a wide angle~~ with a wide angle and a good depth of field and the ability to take close-ups.

16.2.4.4 Filters.

The investigator should know that ~~problems can occur with~~ the use of colored filters is problematic . Unless the end results of colored filter use are known, it is recommended that they not be used. If colored filters are used, the investigator should take an image with a clear filter ~~also~~ as well . ~~The clear~~ An ultra-violet (UV) filter can be used continually as it reduces haze, improves contrast, and is a good means of protecting the lens.

16.2.4.5 Shutter Speed.

~~A minimum amount of light is required for a good exposure. As the aperture is decreased (increased f-stop), the amount of light admitted per unit time decreases, so a longer shutter speed is required. Shutter speeds below 1/60 sec (60) require a tripod to avoid blurring of the image.~~ The shutter speed is the amount of time the shutter remains open during an exposure. A minimum amount of light is needed for a good exposure. As the aperture is decreased (i.e., an increased f-stop), the amount of light admitted per unit time decreases, so a slow shutter speed is necessary. Shutter speeds below 1/60 sec (60) need the use of a tripod to avoid image blur.

16.2.5 Lighting.

The most usable light source ~~known~~ is the sun. No artificial light source can compare ~~realistically~~ in terms of color, definition, and clarity. ~~At the beginning and end of the day, inside a structure or an enclosure, or on an overcast day, a substitute~~ In low-light conditions, or where a burned area has poor reflective properties, a supplemental light source ~~will most likely~~ might be needed. ~~This~~ Supplemental light can be obtained from a light source such as a floodlight, ~~or from a~~ strobe, or flash unit ~~integrated with the camera. Because a burned area has poor reflective properties, artificial lighting using floodlights can be useful~~ .

16.2.5.1

Different light sources give off different color temperatures. Light emitted from an incandescent bulb has a different tint compared to that emitted from a fluorescent light. These different color temperatures are measured in Kelvin. Camera flashes are designed to simulate the color temperature of natural sunlight, which is 5500 Kelvin. The investigator should be aware of white balance and how to adjust their camera equipment. An auto–white balance or a flash-white balance setting is recommended for fire scene photography.

16.2.5.2

There are instances ~~when~~ where the time period during which a photograph was taken will be important to ~~an~~ understand~~ing of~~ what the photograph depicts. In photographs of an identical subject, natural lighting conditions that exist at noon ~~may result in~~ can make a significant~~ly different~~ difference in a photographic image than natural lighting conditions that exist at dusk.

16.2.5.3

Flash units are necessary for the fire investigator's work. A removable flash unit ~~that can be removed from the camera body so that it~~ that can be operated at an angle oblique to that of the lens view may be helpful. This practice is valuable in reducing the amount of reflection, obtaining a greater depth of field, and amplifying the texture of the heat- and flame-damaged surfaces.

16.2.5.4

The use of multiple flash units and remote operating devices called slaves can illuminate large areas.

16.2.5.5

For close-up work, a ring flash will reduce glare and give adequate lighting for the subject matter. ~~Multiple~~ The use of multiple flash units ~~can also be used to~~ at oblique angles to the lens view will give a similar effect to the ring flash ~~by placing them to flash at oblique angles~~ . A ring flash may in some cases “flatten” the image. This can be avoided by using multiple flashes, or by using a standard flash angled downward.

16.2.5.6

The investigator should ~~be sure~~ ensure that glare from a flash or floodlight does not distort the actual appearance of an object. For example, smoke stains could appear lighter or nonexistent. In addition, shadows created could be interpreted as burn patterns. ~~Movie lights used with video cameras~~ Video lighting can cause the same problems as still camera flash units. Using bounce flash, light diffusers, or other techniques may alleviate this problem.

16.2.5.7

The investigator concerned with the ~~potential outcome~~ accurate exposure of a photograph can bracket the exposure. *Bracketing* is the process of taking the same subject matter at slightly different exposure settings to ensure at least one correct exposure. This is generally accomplished by taking a photograph at the recommended f-stop, another at one f-stop below, and another at one f-stop above. Some digital cameras are equipped with a special feature that will perform the bracketing function automatically when selected.

16.2.6 Special Types of Photography.

~~Today's technology has produced some specialty~~ Special types of photography~~.~~ , including ~~Infrared~~ infrared , x-ray, laser, panoramic, macro, high dynamic range, and microscopic photography, can be used under controlled circumstances. ~~An~~ For example ~~is the ability of~~ , laser photography ~~to~~ can be used to document a latent fingerprint found on a body.

16.2.6.1 Composition and Techniques.

16.2.6.1.1

Photographs may be the most persuasive factor in the acceptance of the fire investigator's theory of the fire's evolution.

16.2.6.1.2

In fire investigation, ~~a series of images~~ photographs should be taken to portray the structure and contents that remain at the fire scene. The investigator ~~generally takes a series of images, working from the outside toward the inside of a structure, as well as from the unburned toward the most heavily burned areas. The concluding images are usually of the area and point of origin, as well as any elements of the cause of the fire. Deviations from the general photography sequence described in this section do not necessarily indicate faulty investigative methodology~~ should be aware that the order in which the photographs are taken is recorded in the metadata .

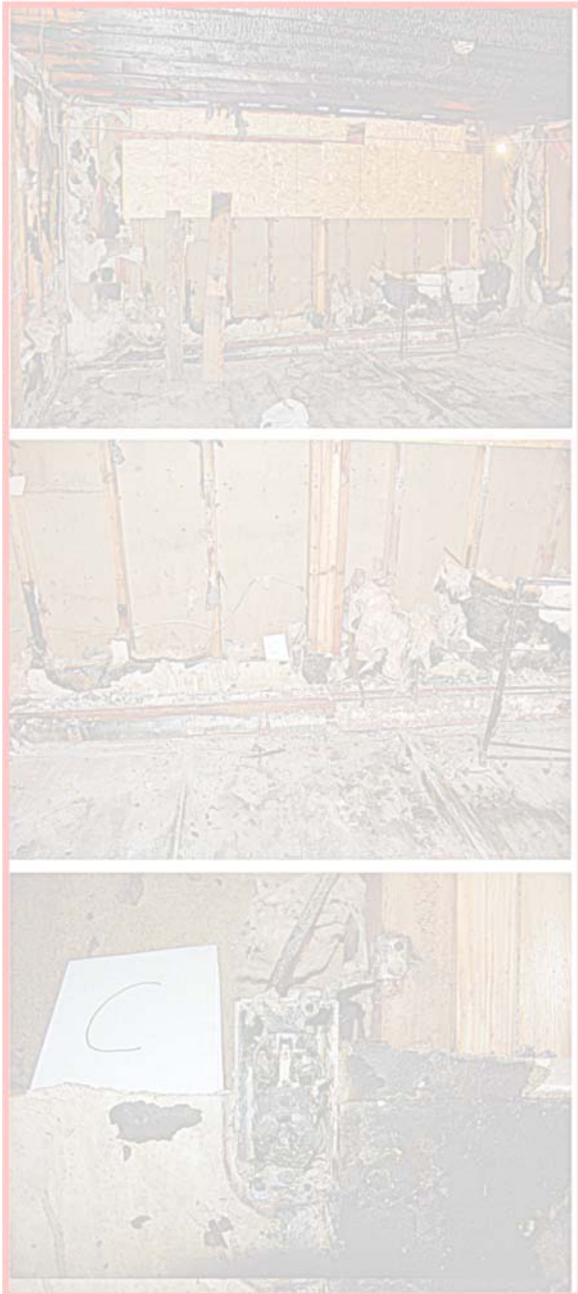
16.2.6.1.3

~~It is important for the photographer to record, and thereby~~ The investigator should document, the entire fire scene and not just the ~~suspected point~~ hypothesized area(s) of origin, as it may be necessary to show the sequence of fire spread, the degree of smoke spread ~~or~~ , evidence of undamaged areas, and evidence of alternative hypotheses .

16.2.5.1.4 Sequential Photos.

Sequential photographs, shown in Figure 16.2.4.2 , are helpful in understanding the relationship of a small subject to its relative position in a known area. The small subject is first photographed from a distant position, where it is shown in context with its surroundings. Additional images are then taken increasingly closer until the subject is the focus of the entire frame.

Figure 16.2.5.1.4 Sequential Photographs of an Outlet.



16.2.6.2 Sequential ~~Photos~~ Photographs .

Sequential photographs, shown in Figure 16.2.6.2~~Figure 16.2.4.2~~ , are helpful in understanding the relationship of a small subject to its relative position in a known area. The small subject is first photographed from a distant position, where it is shown in context with its surroundings. Additional ~~images~~ photographs are then taken increasingly closer until the subject is the focus of the entire frame.

Figure 16.2.6.2 Sequential Photographs of an Outlet.

16.2.6.3 Mosaic Photographs.

Creating mosaic or panoramic photographs can be useful ~~at times~~ when ~~a sufficiently wide angle lens is not available and~~ a panoramic view is desired. A mosaic is created by physically assembling a number of photographs in overlay form to give a more-than-peripheral view of an area, as shown in Figure 16.2.6.3~~Figure 16.2.4.3~~ . The investigator needs to identify benchmark items about ⅓ of the image in from the edge of the view finder that will appear in the print and take the next photograph in the series with that same reference point on the opposite side of the view finder. The two or more individual prints can then be combined to obtain a wider view than the camera is capable of taking in a single shot. Many digital cameras have a preprogrammed feature that when selected, automatically adjusts the camera for taking a seamless panoramic image.

Figure 16.2.6.3 Three Individual Sequential Photographs of a Burned Wooden Pallet Factory (top), Made into a Physically Overlapped Mosaic (bottom).

16.2.6.3.1 Digitally "Stitched" Mosaics.

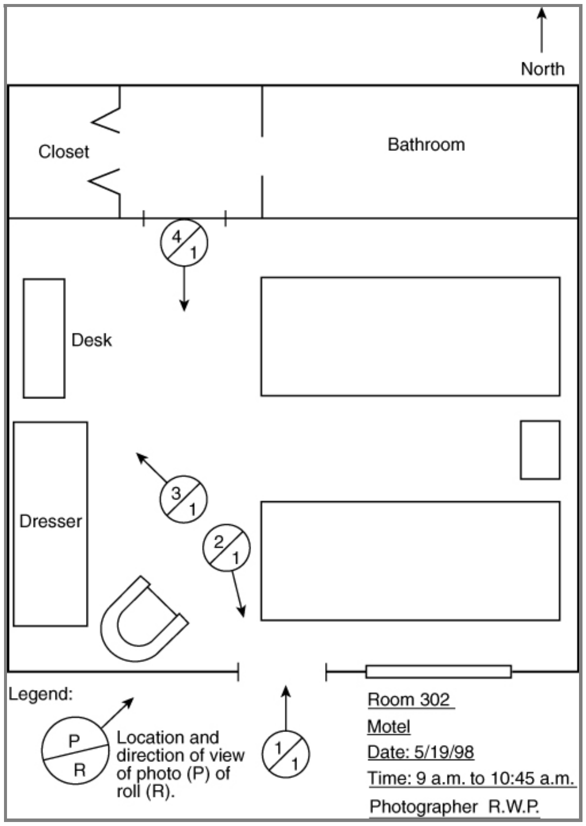
Digital stitching computer programs ~~are available to automatically perform the making of~~ can create mosaic images from a series of digital photos. ~~These~~ Many of these programs ~~frequently~~ offer the ability to adjust and correct the brightness and contrast as well as the "fisheye lens" effect (i.e., aspect ratio) of the completed mosaic image. *(See Figure 16.2.6.3.1~~Figure 16.2.4.3.1~~ .)*

Figure 16.2.6.3.1 Physically Overlapped Mosaic from Figure 16.2.4.3 (top) Compared to a Digitally Stitched Copy of the Mosaic (bottom).

16.2.6.4 Photo Diagram.

A photo diagram can be useful to the investigator. When the finished product of a floor plan is complete, it can be copied, and directional arrows can be drawn to indicate the direction ~~from which each of the photographs was taken~~ the camera was pointed . ~~Numbers corresponding to the frame~~ The arrows are then ~~placed on the images~~ labeled with numbers corresponding to the image they represent . This diagram will ~~assist in~~ help orient~~ing a~~ viewers who ~~is~~ are unfamiliar with the fire scene. A diagram prepared ~~to log~~ for a set of images might appear as shown in Figure 16.2.6.4~~Figure 16.2.4.4~~ . Recommended documentation includes identification of the photographer, identification of the fire scene (i.e., address or incident number), and the date that the photographs were taken. A title form can be used for the first image to record this photo documentation.

Figure 16.2.6.4 Diagram Showing Photo Locations.



~~**16.2.5.4.1**~~

~~Recommended documentation includes identification of the photographer, identification of the fire scene (i.e., address or incident number), and the date that the photographs were taken. A title form can be used for the first image to record this photo documentation.~~

~~**16.2.5.4.2**~~

~~Provided the camera has been properly set up, digital cameras automatically record date and time for each image in a "meta-data" file.~~

16.2.6.5 Assisting Photographer.

~~The investigator should take his own photographs, if possible.~~ If it is necessary for a person other than ~~the~~ a fire investigator ~~is required~~ to take the photographs, the angles and composition should be supervised by the fire investigator to ensure that all of the appropriate ~~images~~ photographs needed to document the fire are obtained. Investigators should communicate their needs to the photographer, as they may not have a chance to return to the fire scene. The investigators should not assume that the photographer understands what essential photographs are needed without discussing the content of each photo.

16.2.6.6 Photography and the Courts.

For the fire investigator to weave photographs and testimony together in the courtroom, one requirement in all jurisdictions is that the ~~image~~ photographs ~~should~~ must be relevant to the testimony. ~~There are other~~ Other requirements ~~that~~ may exist ~~in other~~ depending upon the jurisdiction~~s~~ , including noninflammatory content, clarity of the ~~image~~ photograph , or lack of distortion. In most courts, if ~~the~~ relevancy exists, the image will usually withstand objections.

16.2.7 Video.

Video is a very useful tool to the fire investigator. A great advantage to video is the ability to orient the fire scene by progressive movement of the viewing angle, linking together . In some ways, it combines the use of the photo diagram, photo indexing, floor plan diagram, and still photos into a single operation. Digital video technology has advanced so much so that digital video capabilities are commonplace. Most digital cameras now provide the photographer with the ability to take both still photographs and video images, with many equipped to do both simultaneously.

16.2.7.1

The videographer's movements should be at a slow pace. When taking videos or movies, excessive "zooming" Excessive zooming and panning or otherwise exaggerating an object should be avoided. Excessive zooming can have an adversely affect on the viewer, and be more confusing than a presentation of the video without such effects and should be avoided . In general, video documentation of the scene should be recorded with the minimum number of comments required to orient the viewer. It is recommended that the audio portion of the recording be muted during the videography of the scene.

16.2.7.2

Another use of video is for interviews of witnesses, when the documentation of their testimony is important. If demeanor is important to an investigator or to a jury, the video can be helpful in revealing that. Video can be used for documenting witness interviews, perspectives, activities, and locations.

16.2.7.3

One added benefit of video Video recording is that the investigator can better recall of the fire scene can be used for documenting , specifically fire patterns or artifact evidence, their location, and other important elements of the fire scene. The recording is not necessarily for the purpose of later presentation, but is simply another method by which the investigator can record and document the fire scene.

16.2.7.4

Video recording can also be effective to document the examination of evidence, especially destructive examination. By videotaping video recording the examination, the condition and position of particular elements of evidence can be documented in real time.

16.2.7.5

The exclusive use of video is not recommended. Still photography remains the preferred method to visually document a fire scene investigation. Video is more effective when should only be used in conjunction with and as a supplement to still photographs.

16.2.8 Suggested Activities to Be Documented.

An investigation may be enhanced if as many aspects of the fire ground activities can be documented as possible or practical. Such documentation may include the condition of the scene upon arrival (i.e., with a dashboard camera), the suppression activities, overhaul, and the origin and cause investigation.

16.2.8.1 During the Fire.

Images Photographs and video of the fire in progress should be taken if the opportunity exists. These help show the fire's progression as well as fire department operations. Fire suppression activities pertinent to the investigation include the operation of automatic systems as well as the activities of the responding fire services, whenever possible. All aspects pertinent to these, such as hydrant locations, engine company positions, hose-lays, and attack line locations, and so forth, , all of which can play a role in the eventual outcome of the fire.

16.2.8.2 Overhaul Photographs.

As the overhaul phase often involves moving the contents and sometimes structural elements, when possible, photographing before and during the overhaul phase will assist in understanding the scene before the fire.

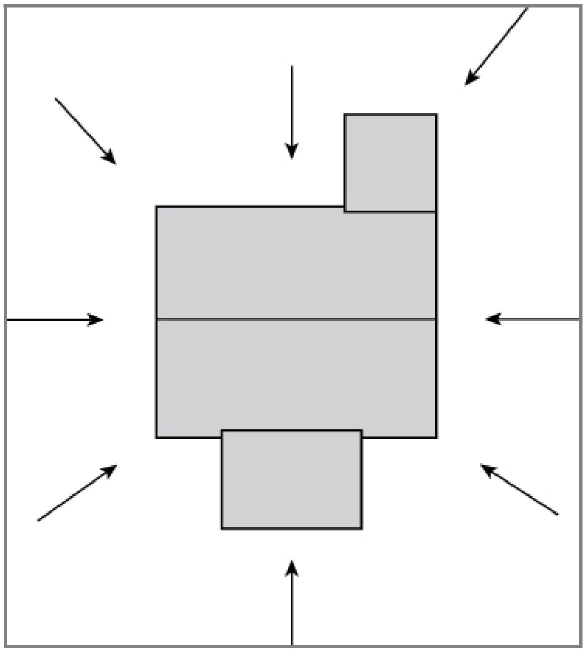
16.2.8.3 Bystander Photographs.

Photographs of people in a crowd are often valuable for identifying individuals who may have additional knowledge that can be valuable to the overall investigation.

16.2.8.4 Exterior Photographs.

A series of exterior shots should be taken to establish the location of a fire scene. These ~~shots~~ photographs could include street signs or access streets, numerical addresses, or landmarks that can be readily identified and are likely to remain for some time. Surrounding areas that would represent remote evidence, such as fire protection and exposure damage, should also be photographed. Exterior photographs should also be taken of all sides and corners of a structure to reveal all structural members and their relationships with each other. *(See Figure 16.2.8.4~~Figure 16.2.6.4~~ .)*

Figure 16.2.8.4 Photographing the Scene from All Angles and Corners.



16.2.8.5 Structural Photographs.

Structural photographs document the damage to the structure after heat and flame exposure. Structural photos can expose burn patterns that can track the evolution of the fire and can assist in understanding the fire's origin.

16.2.8.5.1

A recommended procedure is to include as much as possible with all exterior angles and views of the structure. Oblique corner ~~shots~~ photographs can give reference points for orientation. Photographs should show all angles necessary for a full explanation of a condition.

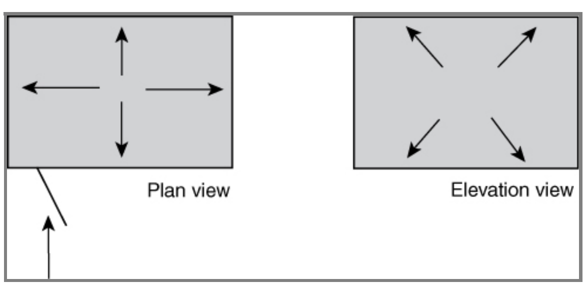
16.2.8.5.2

Photographs should be taken of structural failures such as windows, roofs, or walls, because such failures can change the route of fire travel and can play a significant role in the eventual outcome of the fire. Code violations or structural deficiencies should also be photographed because fire travel patterns may have resulted from those deficiencies.

16.2.8.6 Interior Photographs.

Interior photographs are ~~equally~~ just as important. Lighting conditions will likely change from the exterior, calling for the need to adjust technique, but the concerns, such as ~~(~~ tracking and documenting fire travel backward toward the fire origin~~)~~ , are the same. ~~All significant ventilation points accessed or created by the fire should be photographed, as well as all significant smoke, heat, and burn patterns.~~ Figure 16.2.8.6~~Figure 16.2.6.6~~ provides a diagram of basic shots.

Figure 16.2.8.6 Photographing All Four Walls, the Floor, the Ceiling/~~roof~~ Roof , and Both Sides of Each Door.



16.2.8.6.1

Rooms within the ~~immediate area of the fire origin~~ fire scene should be photographed, even if there is no damage. If warranted, closets and cabinet interiors should also be documented. In small buildings, this documentation could involve all rooms; but in large buildings, it may not be necessary to photograph all rooms unless there is a need to document the presence, absence, or condition of contents.

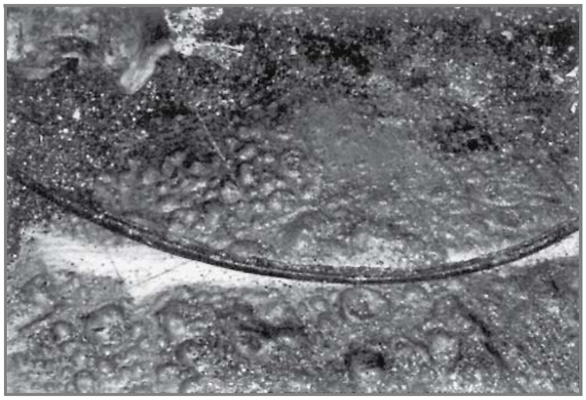
16.2.8.6.2

All heat-producing appliances or equipment, such as furnaces, ~~in the immediate area of the origin or connected to the area of origin~~ within the fire scene should be photographed to document their role, if any, in the fire cause. The position of controls on those devices or equipment that are relevant to the investigation should be photographed. Likewise, all electrical cords and convenience outlets pertinent to the fire's location should be photographed.

16.2.8.6.3

All furniture ~~or~~ and other contents within the ~~area of origin~~ the fire scene should be photographed as found ~~and again after reconstruction~~ . Furniture and other contents involved and uncovered during the excavation and reconstruction should be photographed throughout the process and again after reconstruction. Protected areas left by any furnishings or other contents should also be photographed, as in the example shown in Figure 16.2.8.6.3~~Figure 16.2.6.6.3~~ .

Figure 16.2.8.6.3 Floor Tile Protected from Radiant Heat by Wire.



16.2.8.6.4

The positions , conditions, and associated patterns of doors and windows ~~during a fire is important, so photographs~~ should be ~~taken that would~~ documented ~~those indications and resulting patterns~~ .

16.2.8.6.5

Ventilation openings, whether existent pre- or post-incident, and associated patterns, should be documented.

16.2.8.6.6

Interior fire protection devices such as ~~detectors~~ fire detection and alarm equipment , sprinklers, fire extinguishers ~~used~~ , door closers, ~~or~~ and dampers should be photographed.

16.2.8.6.7

Clocks may indicate the time power was discontinued to them or the time in which fire or heat physically stopped their movement. Caution must be used when interpreting ~~battery operated~~ battery-operated clocks as they may have stopped before the fire or continued to work after the fire.

16.2.8.7 Utility ~~and Appliance~~ Photographs.

The utility (e.g., gas, electric) entrances and controls both inside and outside a structure should be photographed. ~~Photos~~ Photographs should include gas and electric meters, gas regulators, and their location relative to the structure. The electric utility pole~~(s) near the structure that~~ is equipped with the transformer serving the structure~~, and~~ the electrical services coming into the structure, ~~as well as~~ and the fuse or circuit breaker panels, should also be photographed. ~~If there are gas appliances in the fire area of origin, the position of all controls on the gas appliances should be photographed. When photographing electrical~~ Electrical circuit breaker panels, the position of all circuit breaker handles and the panel's legend, when available, ~~schedule indicating what electrical equipment is supplied by each breaker, when available,~~ should be photographed. ~~Likewise, all electrical cords and convenience outlets pertinent to the fire's location should be photographed.~~

16.2.8.8 Evidence Photographs.

Items of evidentiary value should be photographed at the scene and can be re-photographed at the investigator's office or laboratory if a more detailed view is needed. During the excavation of the debris strata, articles in the debris may or may not be recognized as evidence. If photographs are taken in an archaeological manner, the location and position of evidence that can be of vital importance will be documented permanently. Photographs orient the articles of evidence in their original location as well as show their condition when found. ~~Evidence is essential in any court case, and the photographs of evidence stand strong with proper identification.~~ In an evidentiary photograph, a ruler can be used to identify relative size of the evidence. Other items can also be used to identify the size of evidence as long as the item is readily identifiable and of constant size (e.g., a penny). A photograph should be taken of the evidence without the ruler or marker prior to taking a photograph with the marker *(see 17.5.2.1)*.

16.2.8.9 Victim Photographs.

The locations of ~~occupants~~ victims should be documented, and any evidence of actions taken or performed by those ~~occupants~~ victims should be photographed. This documentation should include marks on walls, beds victims were occupying, or protected areas where a body was located. *(See Figure 16.2.8.9~~Figure 16.2.6.9~~ .)* If there is a death involved, the body should be photographed in place if possible . Surviving victims' injuries and their clothing worn should also be photographed.

Figure 16.2.8.9 Protected Area Where Body Was Located.

16.2.8.10 Witness Viewpoint Photographs.

During an investigation, if witnesses surface and give testimony as to what they observed from a certain vantage point, a photograph should be taken from the most identical view available. This photograph will orient all persons involved with the investigation, as well as a jury, to the direction of the witnesses' observations and could support or refute the possibility of their seeing what they said they saw.

16.2.8.11 Aerial Photographs.

Views from an ~~high~~ elevated vantage point, which can be an aerial fire apparatus, adjacent building, ~~or~~ hill, or from an airplane ~~or~~ , helicopter, or drone, can often reveal fire spread patterns. ~~Aerial photography can be expensive, and a number of special problems exist that can affect the quality of the results.~~ It is suggested that the investigator seek the advice or assistance of an experienced aerial photographer when such photographs are desired. *(See Figure 16.2.8.11~~Figure 16.2.6.11~~).*

Figure 16.2.8.11 Aerial Overview of Fire Scene.

16.2.8.12 Satellite ~~Photography~~ Imagery .

Satellite imagery is available in many areas. One of its unique aspects is the possibility of both pre- and ~~post incident~~ post-incident ~~photos~~ images . Depending on the satellite ~~photo~~ schedule, ~~views post fire~~ post-fire views may also be available. Many photos are available on the ~~Web, but NASA may be able to direct you to a source of higher resolution photos~~ Internet .

16.2.9 Photography Tips.

Investigators may help themselves by applying some or all of the photography tips in 16.2.7.1 through 16.2.7.6 The tips in 16.2.9.1 through 16.2.9.6 may assist or improve the investigator's ability to document a fire scene .

16.2.9.1

Upon arrival at a fire scene, a written “title sheet” that shows identifying information (i.e., location, date, or situational information) should be photographed.

16.2.9.2

A The use of a tripod that will allow for a more consistent mosaic pattern photograph , alleviate reduce movement and blurred photographs, and assist in keeping the camera free of fire debris should be available . A quick-release shoe on the tripod will save time is recommended .

16.2.9.3

Extra batteries or battery packs should be carried kept or maintained , especially in cold weather when where they can be drained more quickly. Larger and longerlife Extended battery packs and battery batteries styles are available.

16.2.9.4

Batteries or battery packs should not be left in the photography equipment for an extended periods of time. Leaking batteries or damaged battery packs can cause a multitude of problems to sensitive computer, electrical and mechanical parts.

16.2.9.5

Obstruction of the flash or lens by hands, camera strap, or parts of the fire scene should be avoided.

16.2.9.6

Prior to leaving the scene, a final walk back walk- through of the scene while reviewing your the photographs to taken can ensure that all necessary images have been recorded.

16.2.10* Presentation of Photograph.

A variety of methodologies are available to the investigator for the presentation of reports, diagrams, and photographs. In deciding how to present photographs, the investigator should consider the following:

(1) What method of presentation shows the image with the greatest clarity?

(2) Will the image be used in an instructional format? If so, the investigator should follow guidelines for instructional aids.

(3) What are the requirements of the agency or company requesting the investigation?

(4) What are the requirements of the court where the photographs may be presented?

16.2.10.1 Computer-Based Presentations.

Computer based presentation programs such as PowerPoint and Keynote are now routinely often used for the to presentation of photographs, video, and other documentary evidence.

16.2.10.1.1

Computer-based presentations provide the user with the ability to put drawings and images on the same slide, as well as to provide other highlighting or information that may enhance the observer's ability to understand relationships or information being presented.

16.2.10.1.2

Prior to the presentation, the investigator should ensure that both the physical layout of the courtroom and the judge are amenable to such a presentation. Consideration should be given to the location of the screen and projector so that all parties can observe at the same time.

16.2.10.2 Hard Copy of Presentations.

A hard copy of all material to be presented should be made available to all parties. Some courts will prohibit the investigator from introducing exhibits that have not been timely produced to all sides in accordance with local court rules. The investigator also needs a hard copy in case the presentation equipment fails.

16.2.10 Composition and Techniques.

16.2.10.1

Photographs may be the most persuasive factor in the acceptance of the fire investigator's theory of the fire's evolution.

16.2.10.1.1

In fire investigation, a series of images should be taken to portray the structure and contents that remain at the fire scene. The investigator generally takes a series of images, working from the outside toward the inside of a structure, as well as from the unburned toward the most heavily burned areas. The concluding images are usually of the area and point of origin, as well as any elements of the cause of the fire. Deviations from the general photography sequence described in this section do not necessarily indicate faulty investigative methodology.

16.2.10.1.2

It is important for the photographer to record, and thereby document, the entire fire scene and not just the suspected point of origin, as it may be necessary to show the degree of smoke spread or evidence of undamaged areas.

16.2.10.2 Sequential Photos.

Sequential photographs, shown in Figure 16.2.4.2 , are helpful in understanding the relationship of a small subject to its relative position in a known area. The small subject is first photographed from a distant position, where it is shown in context with its surroundings. Additional images are then taken increasingly closer until the subject is the focus of the entire frame.

Figure 16.2.10.2 Sequential Photographs of an Outlet.

16.2.7.3 Mosaic Photographs.

Creating mosaic or panoramic photographs can be useful at times when a sufficiently wide angle lens is not available and a panoramic view is desired. A mosaic is created by physically assembling a number of photographs in overlay form to give a more-than-peripheral view of an area, as shown in Figure 16.2.4.3 . The investigator needs to identify benchmark items about 1/3 of the image in from the edge of the view finder that will appear in the print and take the next photograph in the series with that same reference point on the opposite side of the view finder. The two or more individual prints can then be combined to obtain a wider view than the camera is capable of taking in a single shot.

Figure 16.2.7.3 Three Individual Sequential Photographs of a Burned Wooden Pallet Factory (top), Made into a Physically Overlapped Mosaic (bottom).

16.2.7.3.1 Digitally "Stitched" Mosaics.

Digital stitching computer programs are available to automatically perform the making of mosaic images from a series of digital photos. These programs frequently adjust and correct the brightness and contrast as well as the "fisheye lens" effect (aspect ratio) of the completed mosaic image. *(See Figure 16.2.4.3.1)*

Figure 16.2.7.3.1 Physically Overlapped Mosaic from Figure 16.2.4.3 (top) Compared to a Digitally Stitched Copy of the Mosaic (bottom).

16.2.10.3 Photo Diagram.

A photo diagram can be useful to the investigator. When the finished product of a floor plan is complete, it can be copied, and directional arrows can be drawn to indicate the direction from which each of the photographs was taken. Numbers corresponding to the frame are then placed on the images. This diagram will assist in orienting a viewer who is unfamiliar with the fire scene. A diagram prepared to log a set of images might appear as shown in Figure 16.2.4.4 .

Figure 16.2.10.3 Diagram Showing Photo Locations.

16.2.10.3.1

Recommended documentation includes identification of the photographer, identification of the fire scene (i.e., address or incident number), and the date that the photographs were taken. A title form can be used for the first image to record this photo documentation.

16.2.10.3.2

Provided the camera has been properly set up, digital cameras automatically record date and time for each image in a "meta-data" file.

16.2.10.4 Assisting Photographer.

The investigator should take his own photographs, if possible. If a person other than the fire investigator is required to take the photographs, the angles and composition should be supervised by the fire investigator to ensure that all of the appropriate images needed to document the fire are obtained. Investigators should communicate their needs to the photographer, as they may not have a chance to return to the fire scene. The investigators should not assume that the photographer understands what essential photographs are needed without discussing the content of each photo.

16.2.10.5 Photography and the Courts.

For the fire investigator to weave photographs and testimony together in the courtroom, one requirement in all jurisdictions is that the image should be relevant to the testimony. There are other requirements that may exist in other jurisdictions, including noninflammatory content, clarity of the image, or lack of distortion. In most courts, if the relevancy exists, the image will usually withstand objections.

16.2.7 Video.

Video is a very useful tool to the fire investigator. A great advantage to video is the ability to orient the fire scene by progressive movement of the viewing angle. In some ways, it combines the use of the photo diagram, photo indexing, floor plan diagram, and still photos into a single operation.

16.2.7.1

When taking videos or movies, excessive "zooming" or otherwise exaggerating an object should be avoided. Excessive zooming can adversely affect the viewer, and be more confusing than a video without such effects. In general, video documentation of the scene should be recorded with the minimum number of comments required to orient the viewer.

16.2.7.2

Another use of video is for interviews of witnesses, when the documentation of their testimony is important. If demeanor is important to an investigator or to a jury, the video can be helpful in revealing that.

16.2.7.3

One added benefit of video recording is that the investigator can better recall the fire scene, specifically fire patterns or artifact evidence, their location, and other important elements of the fire scene. The recording is not necessarily for the purpose of later presentation, but is simply another method by which the investigator can record and document the fire scene.

16.2.7.4

Video recording can also be effective to document the examination of evidence, especially destructive examination. By videotaping the examination, the condition and position of particular elements of evidence can be documented in real time.

16.2.7.5

The exclusive use of video is not recommended. Video is more effective when used in conjunction with still photographs.

16.2.11 Suggested Activities to Be Documented.

An investigation may be enhanced if as many aspects of the fire ground activities can be documented as possible or practical. Such documentation may include the condition of the scene upon arrival (dashboard camera), the suppression activities, overhaul, and the origin and cause investigation.

16.2.9.1 During the Fire.

Images of the fire in progress should be taken if the opportunity exists. These help show the fire's progression as well as fire department operations. Fire suppression activities pertinent to the investigation include the operation of automatic systems as well as the activities of the responding fire services, whenever possible. All aspects pertinent to these, such as hydrant locations, engine company positions, hose-lays, attack line locations, and so forth, play a role in the eventual outcome of the fire.

16.2.9.1

As the overhaul phase often involves moving the contents and sometimes structural elements, photographing the overhaul phase will assist in understanding the scene before the fire.

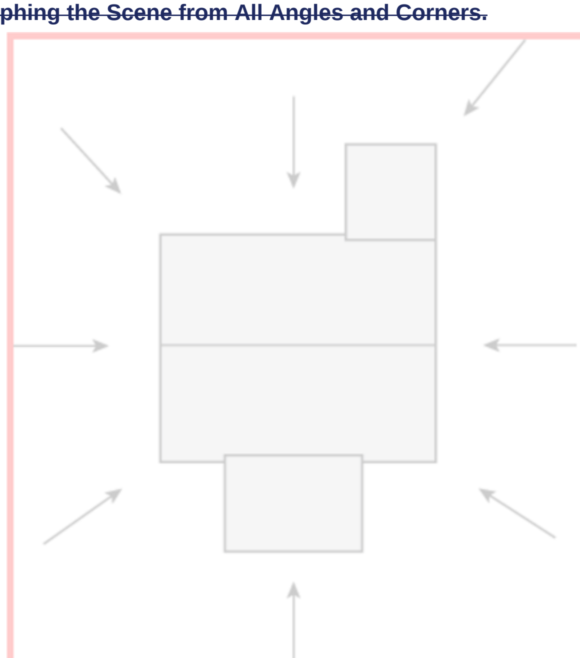
16.2.9.1 Bystander Photographs.

Photographs of people in a crowd are often valuable for identifying individuals who may have additional knowledge that can be valuable to the overall investigation.

16.2.9.1 Exterior Photographs.

A series of exterior shots should be taken to establish the location of a fire scene. These shots could include street signs or access streets, numerical addresses, or landmarks that can be readily identified and are likely to remain for some time. Surrounding areas that would represent remote evidence, such as fire protection and exposure damage, should also be photographed. Exterior photographs should also be taken of all sides and corners of a structure to reveal all structural members and their relationships with each other. *(See Figure 16.2.8.4 Figure 16.2.6.4 .)*

Figure 16.2.9.1 Photographing the Scene from All Angles and Corners.



16.2.9.1 Structural Photographs.

Structural photographs document the damage to the structure after heat and flame exposure. Structural photos can expose burn patterns that can track the evolution of the fire and can assist in understanding the fire's origin.

16.2.9.1.1

A recommended procedure is to include as much as possible all exterior angles and views of the structure. Oblique corner shots can give reference points for orientation. Photographs should show all angles necessary for a full explanation of a condition.

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Photographs should be taken of structural failures such as windows, roofs, or walls, because such failures can change the route of fire travel and can play a significant role in the eventual outcome of the fire. Code violations or structural deficiencies should also be photographed because fire travel patterns may have resulted from those deficiencies.

16.2.9.1 Interior Photographs.

Interior photographs are equally important. Lighting conditions will likely change from the exterior, calling for the need to adjust technique, but the concerns (tracking and documenting fire travel backward toward the fire origin) are the same. All significant ventilation points accessed or created by the fire should be photographed, as well as all significant smoke, heat, and burn patterns. Figure 16.2.8.6 Figure 16.2.6.6 provides a diagram of basic shots.

Figure 16.2.9.1 Photographing All Four Walls, the Floor, the Ceiling/roof, and Both Sides of Each Door.

16.2.9.1.1

Rooms within the immediate area of the fire origin should be photographed, even if there is no damage. If warranted, closets and cabinet interiors should also be documented. In small buildings, this documentation could involve all rooms; but in large buildings, it may not be necessary to photograph all rooms unless there is a need to document the presence, absence, or condition of contents.

16.2.9.1.2

All heat-producing appliances or equipment, such as furnaces, in the immediate area of the origin or connected to the area of origin should be photographed to document their role, if any, in the fire cause.

16.2.9.1.3

All furniture or other contents within the area of origin should be photographed as found and again after reconstruction. Protected areas left by any furnishings or other contents should also be photographed, as in the example shown in Figure 16.2.8.6.3 Figure 16.2.6.6.3 .

Figure 16.2.9.1.3 Floor Tile Protected from Radiant Heat by Wire.

16.2.9.1.4

The position of doors and windows during a fire is important, so photographs should be taken that would document those indications and resulting patterns.

16.2.9.1.5

Interior fire protection devices such as detectors, sprinklers, extinguishers used, door closers, or dampers should be photographed.

16.2.9.1.6

Clocks may indicate the time power was discontinued to them or the time in which fire or heat physically stopped their movement. Caution must be used when interpreting battery operated clocks as they may have stopped before the fire or continued to work after the fire.

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The utility (gas, electric) entrances and controls both inside and outside a structure should be photographed. Photos Photographs should include gas and electric meters, gas regulators, and their location relative to the structure. The electric utility pole (s) near the structure that is equipped with the transformer serving the structure , and the electrical services coming into the structure, as well as and the fuse or circuit breaker panels, should also be photographed. If there are gas appliances in the fire area of origin, the position of all controls on the gas appliances should be photographed. When photographing electrical Electrical circuit breaker panels, the position of all circuit breaker handles and the panel's legend (when available) schedule indicating what electrical equipment is supplied by each breaker, when available, should be photographed. Likewise, all electrical cords and convenience outlets pertinent to the fire's location should be photographed.

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Items of evidentiary value should be photographed at the scene and can be re-photographed at the investigator's office or laboratory if a more detailed view is needed. During the excavation of the debris strata, articles in the debris may or may not be recognized as evidence. If photographs are taken in an archaeological manner, the location and position of evidence that can be of vital importance will be documented permanently. Photographs orient the articles of evidence in their original location as well as show their condition when found. Evidence is essential in any court case, and the photographs of evidence stand strong with proper identification. In an evidentiary photograph, a ruler can be used to identify relative size of the evidence. Other items can also be used to identify the size of evidence as long as the item is readily identifiable and of constant size (e.g., a penny). A photograph should be taken of the evidence without the ruler or marker prior to taking a photograph with the marker *(see 17.5.2.1)* .

16.2.9.1 Victim Photographs.

The locations of occupants should be documented, and any evidence of actions taken or performed by those occupants should be photographed. This documentation should include marks on walls, beds victims were occupying, or protected areas where a body was located. *(See Figure 16.2.9.3 Figure 16.2.6.9 .)* If there is a death involved, the body should be photographed. Surviving victims' injuries and their clothing worn should also be photographed.

Figure 16.2.9.1 Protected Area Where Body Was Located.

16.2.9.2 Witness Viewpoint Photographs.

During an investigation, if witnesses surface and give testimony as to what they observed from a certain vantage point, a photograph should be taken from the most identical view available. This photograph will orient all persons involved with the investigation, as well as a jury, to the direction of the witnesses' observations and could support or refute the possibility of their seeing what they said they saw.

16.2.9.1 Aerial Photographs.

Views from a high vantage point, which can be an aerial fire apparatus, adjacent building, or hill, or from an airplane or helicopter can often reveal fire spread patterns. Aerial photography can be expensive, and a number of special problems exist that can affect the quality of the results. It is suggested that the investigator seek the advice or assistance of an experienced aerial photographer when such photographs are desired. *(See Figure 16.2.9.5 Figure 16.2.6.11)* .

Figure 16.2.9.1 Aerial Overview of Fire Scene.

16.2.9.1 Satellite Photography Imagery.

Satellite imagery is available in many areas. One of its unique aspects is the possibility of both pre and post incident photos images. Depending on the satellite photo schedule, views post fire may also be available. Many photos are available on the Web, but NASA may be able to direct you to a source of higher resolution photos Internet.

16.2.10 Photography Tips.

Investigators may help themselves by applying some or all of the photography tips in 16.2.7.1 through 16.2.7.6 .

16.2.10.1

Upon arrival at a fire scene a written "title sheet" that shows identifying information (i.e., location, date, or situational information) should be photographed.

16.2.10.2

A tripod that will allow for a more consistent mosaic pattern, alleviate movement and blurred photographs, and assist in keeping the camera free of fire debris should be available. A quick-release shoe on the tripod will save time.

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Extra batteries should be carried, especially in cold weather when they can be drained quickly. Larger and longerlife battery packs and battery styles are available.

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Batteries should not be left in the photography equipment for an extended period of time. Leaking batteries can cause a multitude of problems to electrical and mechanical parts.

16.2.10.5

Obstruction of the flash or lens by hands, camera strap, or parts of the fire scene should be avoided.

16.2.10.6

Prior to leaving the scene, walk back through the scene while reviewing your photographs to ensure that all necessary images have been recorded.

16.2.11* Presentation of Photograph.

A variety of methodologies are available to the investigator for the presentation of reports, diagrams, and photographs. In deciding how to present photographs, the investigator should consider the following:

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Will the image be used in an instructional format? If so, the investigator should follow guidelines for instructional aids.

What are the requirements of the agency or company requesting the investigation?

What are the requirements of the court where the photographs may be presented?

16.2.11.1 Computer-Based Presentations.

Computer based presentation programs such as PowerPoint and Keynote are now routinely used for the presentation of photographs, video and other documentary evidence.

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Computer-based presentations provide the user with the ability to put drawings and images on the same slide, as well as to provide other highlighting or information that may enhance the observer's ability to understand relationships or information being presented.

~~16.2.11.1.2~~

~~Prior to the presentation, the investigator should ensure that both the physical layout of the courtroom and the judge are amenable to such a presentation. Consideration should be given to the location of the screen and projector so that all parties can observe at the same time.~~

~~16.2.11.2~~

~~A hard copy of all material to be presented should be made available to all parties. Some courts will prohibit the investigator from introducing exhibits that have not been timely produced to all sides in accordance with local court rules. The investigator also needs a hard copy in case the presentation equipment fails.~~

Supplemental Information

File Name	Description
Staff_only_FR_57_Section_16.2.docx	1. Revised section 16.2 and associated annexes.

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
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Committee Statement

Committee Statement: This submitted text revises the existing text in paragraphs 16.2 through 16.2.8 of the current document. The committee has made these revisions to clarify and enhance the text bringing it up to date with digital photography.

Response Message:

First Revision No. 54-NFPA 921-2015 [Section No. 16.3]

16.3 Note Taking.

Note taking is a method of documentation in addition to drawings and photographs. Items that may need to be documented in notes ~~may~~ include the following:

(1) Names and addresses

(2) Model/serial numbers

(3) Statements and interviews

(4) Photo log

(5) Identification of items (e.g., contents and furnishings)

(6) Types and form of materials (e.g., wood paneling, foam plastic, carpet)

(7) Data ~~that was~~ needed to produce an accurate computer model *(see ~~Section~~ ~~22.6~~ Chapter 22)*

(8) Investigator observations (e.g., ~~burn~~ fire effects and patterns, building conditions, position of switches and controls)

16.3.1 Forms of Incident Field Notes.

The collection of data concerning an investigation is important in the analysis of any incident. The use of forms is not required in data collection; however, some forms have been developed to assist the investigator in the collection of data. These example forms and the information documented are not designed to constitute the report but~~, rather, they~~ instead provide a means to gather data that may be helpful in reaching conclusions so that a report can be prepared. *(See A.16.3.2 .)*

16.3.2* Forms for Collecting Data.

Some forms have been developed to assist the investigator in the collection of data. These forms and the information documented on them are not designed to constitute the incident report. They provide a means to gather data that may be helpful in reaching conclusions so that the incident report or the investigation report can be prepared. *(See Table 16.3.2 .)*

Table 16.3.2 Field Notes and Forms

Form	Purpose
Fire incident field notes	Any fire investigation to collect general incident data
Casualty field notes	Collection of general data on any victim killed or injured
Wildfire field notes	Data collection specifically for wildfire
Evidence form	Documentation of evidence collection and chain of custody
Vehicle inspection form	Data collection of incidents specifically involving motor vehicles
Photograph log	Documentation of photographs taken during the investigation
Electrical panel documentation	Collection of data specifically relating to electrical panels
Structure fire notes	Collection of data concerning structure fires
Insurance information	Documentation of insurance coverage for fire loss
Records/documents	Documentary records considered in the investigation
Compartment fire modeling	Collection of data necessary for compartment fire modeling

16.3.3 Dictation of Field Notes.

Many investigators dictate their notes using portable tape recorders or digital devices . Investigators should be careful not to rely solely on tape recorders or any single piece of equipment when documenting critical information or evidence.

16.3.4

The retention of original notes, diagrams, photographs, and measurements ~~such~~ as detailed in Section 16.3 is the best practice. Unless otherwise required by a written policy or regulation, such data should be retained. These data constitute a body of factual information that should be retained until all reasonably perceived litigation processes are resolved. Information collected during the investigation may become significant long after it is collected and after the initial report is written. For example, notes or a diagram of a circuit breaker panel showing the status of the breakers may not be pertinent for a fire where the origin is in upholstered furniture, but may be of value regarding the status of the circuit powering a smoke ~~detector. The retention of notes is not necessarily intended to apply to the fire fighter completing the required data fields in a fire incident reporting system~~ alarm .

Supplemental Information

File Name	Description
Staff_only_FR_54_Table_16.3.2.docx	1. Changes to Table 16.3.2.

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Committee Statement

Committee Statement: The submitted text revises the current text in section 16.3 of the current document. The committee has made these revisions to clarify and enhance the text.

Response Message:

First Revision No. 60-NFPA 921-2015 [Section No. 16.4.5.6]

16.4.5.6* Three-Dimensional (3D) Representations.

In many cases, it ~~will~~ may be ~~desirable, if not~~ necessary~~,~~ for the investigator to obtain sufficient dimensional data to develop a ~~three-dimensional~~ 3D representation of the fire scene. Various 3D tools can assist fire and explosion investigators in providing accurate 3D representations of the scene in advance of a fire or explosion, during an active incident, and for post incident analysis. These tools include the use of photogrammetry, total stations, and high-definition laser scanning (HDS LiDAR). The 3D scene or "model" provides new opportunities for investigators to test hypotheses via witness viewpoints, computational fluid dynamic, and a true color, true scale, and sharable virtual scene. Three D data capture techniques provide a way to document perishable evidence, spatial relativity of fuels, compartments, and ventilation openings and flow paths.

16.4.5.6.1 Structural Dimensions.

The investigator should measure and document dimensions that would be ~~required~~ needed to develop an accurate ~~three-dimensional~~ 3D representation of the structure, as illustrated in Figure 16.4.2(c). Consideration should be given to the documentation of such often overlooked dimensions as the thickness of walls, air gaps in doors, and the slope of floors, walls, and ceilings. Such representative geometry may be ~~required~~ needed if subsequent fire modeling and/or experimental tests are ~~to be~~ conducted as part of the incident investigation.

16.4.5.6.2 Availability of Dimensional Data.

While dimensional data may be found in building plans, layouts, or as-built drawings, it may not be known at the time of the scene investigation if such sources of information exist, especially in the case of older structures. Thus, it is prudent for the investigator to collect the physical dimensions independent of the existence of plans, layouts, or drawings.

Supplemental Information

File Name	Description
FR_60_A.16.4.5.6.docx	1. New annex A.16.4.5.

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Public Input No. 43-NFPA 921-2014 [Section No. 16.4.5.6 [Excluding any Sub-Sections]]

Annex A Explanatory Material

Annex A is not a part of the recommendations of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.16.4.5.6 For more information see:

Reference: Icove, J. I., DeHaan, J.D., & Haynes, G.A. (2012). “Forensic Fire Scene Reconstruction (3 ed.).” Maryland: Brady Books, a division of Pearson. Chapter 4: Pages 175-182

John D., D., & Icove, D.J. (2011). “Kirk’s Fire Investigation (7 ed.).” Maryland: Brady Books, a division of Pearson. Pages 245-246 and 521-522.

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First Revision No. 55-NFPA 921-2015 [Section No. 16.5]

16.5* Reports.

~~The purpose of a report is to effectively communicate the observations, analyses, and conclusions made during an investigation. The specific format of a report is not prescribed. For guidance on court-mandated reports, see Chapter 12 .~~ The final step in the documentation of the investigation may be the preparation and submittal of a report. The format and content of the report will depend on the needs of the organization or client on whose behalf the investigation was performed. Therefore, no report format is prescribed here. However, for guidance on court-mandated reports, see Chapter 12 .

16.5.1 Purpose.

The purpose of a written report is to document an accurate and concise reflection of the investigator's findings. The report should contain facts and data that the investigator can rely on to render any opinions and should contain the investigator's reasoning of how each opinion was reached. The report should meet the needs or requirements of the intended audience(s). Reports may be used for: improvement of public safety, prevention of similar future incidents, the basis for criminal or civil litigation, the basis for insurance claims, or simply documentation of the facts for the record. *(See A.4.3.6 of NFPA 1033 .)*

16.5.2 Report Organization.

The investigator should develop and organize a report to provide the desired information of the party requesting the report. The investigator should know that a cursory report may not meet the requirements or the needs of a jurisdiction and NFPA 1033 .

16.5.3 Descriptive Information.

~~Generally, reports should contain the following information, preferably in the introduction:~~ The following information is usually found in a report:

(1) Date the report was submitted

(2) Date, time, and location of incident

(3) Date and location of examination(s)

~~Date the report was prepared~~

(4) Name of the person or entity requesting the report

(5) The scope of the investigation (i.e., tasks assigned and tasks completed)

(6) Nature of the report (e.g., preliminary, interim, final, summary, supplementary)

(7) Name of person(s) preparing the report

16.5.4 Opinions and Conclusions.

~~The report should contain the opinions and conclusions rendered by the investigator. The report should also contain the foundation(s) on which the opinion and conclusions are based. The name, address, and affiliation of each person who has rendered an opinion contained in the report should be provided.~~ The report should contain the investigator's opinions and conclusions in a clear, delineated section, whether at the beginning or the end of the report. The reader should not have to search the report looking for opinions and conclusions in a narrative or analysis section. The report should also state the basis or bases for each opinion and conclusion. The name, address, and affiliation of each person who has contributed to the work or rendered an opinion contained in the report, other than the report author, should also be provided.

16.5.5 Pertinent Facts.

~~A description of the incident scene, items examined, and evidence collected should be provided. The report should contain observations and information relevant to the opinions. Photographs, diagrams, and laboratory reports may be referenced.~~ A description of the incident scene, dates and times when visited, items examined, and relevant evidence collected should be provided. If subsequent examination and testing of evidence took place, dates and places should be documented. The observations and information contained in the report should be those relevant to the opinions. Supporting material such as photographs, diagrams, evidence lists, and laboratory reports may be included in appendices.

16.5.6 Reference to Methodology.

When the investigator states that the scientific method was used (see Section 4.3) to determine origin and cause, the report should give sufficient detail to show that the methodology was indeed used and not just cited.

~~**16.5.5** Opinions and Conclusions.~~

~~The report should contain the opinions and conclusions rendered by the investigator. The report should also contain the foundation(s) on which the opinion and conclusions are based. The name, address, and affiliation of each person who has rendered an opinion contained in the report should be provided.~~

Supplemental Information

File Name	Description
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Response Message:

First Revision No. 64-NFPA 921-2015 [Section No. 17.5.4]

17.5.4 Collection of Evidence for Accelerant Testing.

An accelerant is any fuel or oxidizer, often an ignitible liquid, used to initiate a fire or increase the rate of growth or speed the spread of fire. Accelerant may be found in any state~~:~~ — gas, liquid, or solid. Evidence for accelerant testing should be collected and tested in accordance with ~~ASTM E1387, *Standard Test Method for Ignitible Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography*, or with~~ ASTM E1618, *Standard Test Method for Ignitible Liquid Residues in Extracts from Fire Debris by Gas Chromatography–Mass Spectrometry*.

17.5.4.1 Liquid Accelerant Characteristics.

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

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

(2) Generally, liquid accelerants float when in contact with water ~~(~~ ; however, alcohol is a noted exception~~)~~ .

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

17.5.4.2 Canine/Handler Teams.

When a canine/handler team is used to detect possible evidence of accelerant use, the handler should be allowed to decide what areas ~~(~~ , if any~~)~~ , of a building or site to examine. Prior to any search, the handler should carefully evaluate the site for safety and health risks such as collapse, falling, toxic materials, residual heat, and vapors, and should be the final arbiter of whether the canine is allowed to search. It should also be the handler's decision whether to search all of a building or site, even areas not involved in the fire. The canine/handler team can assist with the examination of ~~debris (~~ loose or packaged~~)~~ debris removed from the immediate scene as a screening step to confirm whether the appropriate debris has been recovered for laboratory analysis.

17.5.4.3 Collection of Liquid Samples for Ignitible Liquid Testing.

When a possible ignitible liquid is found in a liquid state, it can be collected using any one of a variety of methods. ~~Whichever method is employed, however~~ However , the fire investigator should be certain that the evidence does not become contaminated by whichever method is employed . If readily accessible, the liquid may be collected with a new syringe, eye dropper, pipette, siphoning device, or the evidence container itself. Sterile cotton balls or gauze pads may also be used to absorb the liquid. This method of collection results in the liquid becoming absorbed by the cotton balls or gauze pads. The cotton balls or gauze pads and their absorbed contents then become the physical evidence that should be sealed in an airtight container and submitted to the laboratory for examination and testing.

17.5.4.4 Collection of Liquid Evidence Absorbed by Solid Materials.

Often, liquid accelerant evidence may be found only where the liquid accelerant has been absorbed by solid materials, including soils and sands. This method of collection merely involves the collection of these solid materials with their absorbed contents. The collection of these solid materials may be accomplished by scooping them with the evidence container itself or by cutting, sawing, or scraping. Raw, unsealed, or sawed edges, ends, nail holes, cracks, knot holes, and other similar areas of wood, plaster, sheet rock, mortar, or even concrete are particularly good areas to sample. If deep penetration is suspected, the entire cross-section of material should be removed and preserved for laboratory evaluation. In some solid material, such as soil or sand, the liquid accelerant may absorb deeply into the material. The investigator should therefore remove samples from a greater depth. In those situations where liquid accelerants are believed to have become trapped in porous material, such as a concrete floor, the fire investigator may use absorbent materials such as lime, diatomaceous earth, or non-self-rising flour. This method of collection involves spreading the absorbent onto the concrete surface, allowing it to stand for 20 to 30 minutes, and securing it in a clean, airtight container. The absorbent is then extracted in the laboratory. The investigator should be careful to use clean tools and containers for the recovery step, because the absorbent is easily contaminated. A sample of the unused absorbent should be preserved separately for analysis as a comparison sample.

17.5.4.5 Collection of Solid Samples for Accelerant Testing.

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

17.5.4.6* Comparison Samples.

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

17.5.4.6.1

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

17.5.4.6.2

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

17.5.4.6.3

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

17.5.4.6.4

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

17.5.4.7* Canine Teams.

Properly trained and validated ignitible liquid detection canine/handler teams have proven their ability to improve fire investigations by assisting in the location and collection of samples for laboratory analysis for the presence of ignitible liquids. The proper use of detection canines is to assist with the location and selection of samples.

17.5.4.7.1

In order for the presence or absence of an ignitible liquid to be scientifically confirmed in a sample, that sample should be analyzed by a laboratory in accordance with 17.5.3. Any canine alert not confirmed by laboratory analysis should not be considered validated.

17.5.4.7.2*

Research has shown that canines have responded or have been alerted to pyrolysis products that are not produced by an ignitible liquid and have not always responded when an ignitible liquid accelerant was known to be present. If an investigator feels that there are indicators of an accelerant, samples should be taken even in the absence of a canine alert.

17.5.4.7.3

The canine olfactory system is believed capable of detecting gasoline at concentrations below those normally cited for laboratory methods. The detection limit, however, is not the sole criterion or even the most important criterion for any forensic technique. Specificity, the ability to distinguish between ignitible liquids and background materials, is even more important than sensitivity for detection of any ignitible liquid residues. Unlike explosive- or drug-detecting dogs, these canines are trained to detect substances that are common to our everyday environment. The techniques exist today for forensic laboratories to detect submicroliter quantities of ignitible liquids, but because these substances are intrinsic to our mechanized world, merely detecting such quantities is of limited evidential value.

17.5.4.7.4*

Current research does not indicate which individual chemical compounds or classes of chemical compounds are the key “triggers” for canine alerts. Research reveals that most classes of compounds contained in ignitible liquids may be produced from the burning of common synthetic materials. Laboratories that use ASTM standards (*see Section 17.10*) have minimum standards that define those chemical compounds that must be present ~~in order~~ to make a positive determination. The sheer variety of pyrolysis products present in fire scenes suggests possible reasons for some unconfirmed alerts by canines. The discriminatory ability of the canine to distinguish between pyrolysis products and ignitible liquids is remarkable but not infallible.

17.5.4.7.5

The proper objective of the use of canine/handler teams is to assist with the selection of samples that have a higher probability of laboratory confirmation than samples selected without the canine's assistance.

17.5.4.7.6

Canine ignitible liquid detection should be used in conjunction with, and not in place of, the other fire investigation and analysis methods described in this guide.

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Committee Statement

Committee Statement: This change updates the text to reflect the new ASTM E 1618 which replaced ASTM E 1387.

Response Message:

First Revision No. 65-NFPA 921-2015 [Sections 17.10.2.1, 17.10.2.2]

17.10.2.1 Gas Chromatography-Mass Spectrometry (GC-MS).

Most ignitible liquids are mixtures containing many different compounds. This test method separates the mixtures of compounds into their individual components by boiling point and then ~~provides a graphical representation of each component and its relative amount~~ further analyzes the individual components that have been separated by providing data about the size of fragments (i.e., ions) that are produced in the mass spectrometer. Methods of GC-MS analysis are described in ASTM E1618, *Standard Test Method for Ignitible Liquid Residues in Extracts from Fire Debris by Gas Chromatography–Mass Spectrometry* . This method is useful for gas or liquid mixtures ~~of gases or liquids~~ that can be vaporized without decomposition. ~~GC is sometimes a preliminary test that may indicate the need for additional testing to specifically identify the components. For most petroleum distillate accelerants, GC provides adequate characterization if conducted according to accepted methods. These methods are described in ASTM E1387, *Standard Test Method for Ignitible Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography* .~~

~~**17.10.2.2** Mass Spectrometry (MS).~~

~~This test method is usually employed in conjunction with gas chromatography. This method further analyzes the individual components that have been separated during gas chromatography. Methods of GC/MS analysis are described in ASTM E1618, *Standard Test Method for Ignitable Liquid Residues in Extracts from Fire Debris by Gas Chromatography–Mass Spectrometry* .~~

Supplemental Information

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Response Message:

First Revision No. 62-NFPA 921-2015 [Section No. 17.10.2.14]

17.10.2.13 Cigarette Ignition Resistance of Mock-up Upholstered Furniture Assemblies.

This test method, from ~~ASTM E1352~~ NFPA 261 , ~~*Standard Test Method for Cigarette Ignition Resistance of Mock-up Upholstered Furniture Assemblies,*~~ is intended to cover the assessment of the resistance of upholstered furniture mock-up assemblies to combustion after exposure to smoldering cigarettes under specified conditions. ~~The test method is technically equivalent to NFPA 261 , *Standard Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes.* Note that the commercial cigarettes~~ Note that the cigarettes used in this test are based on a standard cigarette developed by NIST and designated SRM 1196, and are similar to the commercial cigarettes used before the advent of low-ignition propensity cigarettes. Note also that commercial cigarettes sold in the U.S. are no longer used in the test method and have been ~~deigned~~ designed to be ~~"~~ low-ignition propensity cigarettes~~" as sold in the U.S~~ .

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Committee Statement: The change in the text brings the document current with the test method of date. NFPA 261 has replaced the commercial cigarettes by cigarettes (SRM 1196) that are not "low ignition propensity" and will be able to cause ignition of textile materials. ASTM 1352 is no longer a valid test because it uses commercial cigarettes, which do not ignite typical textile materials.

Response Message:

Public Input No. 166-NFPA 921-2014 [Section No. 17.10.2.14]

First Revision No. 63-NFPA 921-2015 [Section No. 17.10.2.15]

17.10.2.14 Cigarette Ignition Resistance of Components of Upholstered Furniture.

This test method, from ~~ASTM E1353~~ NFPA 260 ~~, *Standard Test Methods for Cigarette Ignition Resistance of Components of Upholstered Furniture*~~ , is intended to evaluate the ignition resistance of upholstered furniture component assemblies when exposed to smoldering cigarettes under specified conditions. ~~The test method is technically equivalent to NFPA 260 , *Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture.* Note that the commercial "cigarettes,"~~ Note that the cigarettes used in the test method are based on a standard cigarette developed by NIST and designated SRM 1196, and they are similar to the commercial cigarettes used before the advent of low-ignition propensity cigarettes. Note also that the commercial cigarettes sold in the U.S. and no longer used in the test method have been ~~deigned~~ designed to be ~~"low ignition~~ low-ignition propensity cigarettes~~" as sold in the U.S~~ .

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Response Message:

Public Input No. 167-NFPA 921-2014 [Section No. 17.10.2.15]

First Revision No. 66-NFPA 921-2015 [Section No. 18.1.2]

18.1.2

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

(1) *Witness Information.* *and/or Electronic Data.* The analysis of observations reported by persons who witnessed the fire or were aware of conditions present at the time of the fire as well as the analysis of electronic data such as security camera footage, alarm system activation, or other such data recorded in and around the time of the fire event

(2) *Fire Patterns.* The analysis of effects and patterns left by the fire *(See see Chapter 6.)*

(3) *Arc Mapping.* The analysis of the locations where electrical arcing has caused damage and the documentation of the involved electrical circuits *(See see Section 9.10.)*

(4) *Fire Dynamics.* The analysis of the fire dynamics, that is [i.e. , the physics and chemistry of fire initiation and growth *(see Chapter 5)*, and the interaction between the fire and the building's systems *(See see Chapter 7.)*]

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Committee Statement

Committee Statement: The additional text recognizes the importance of visual and electronic information to the determination of origin.

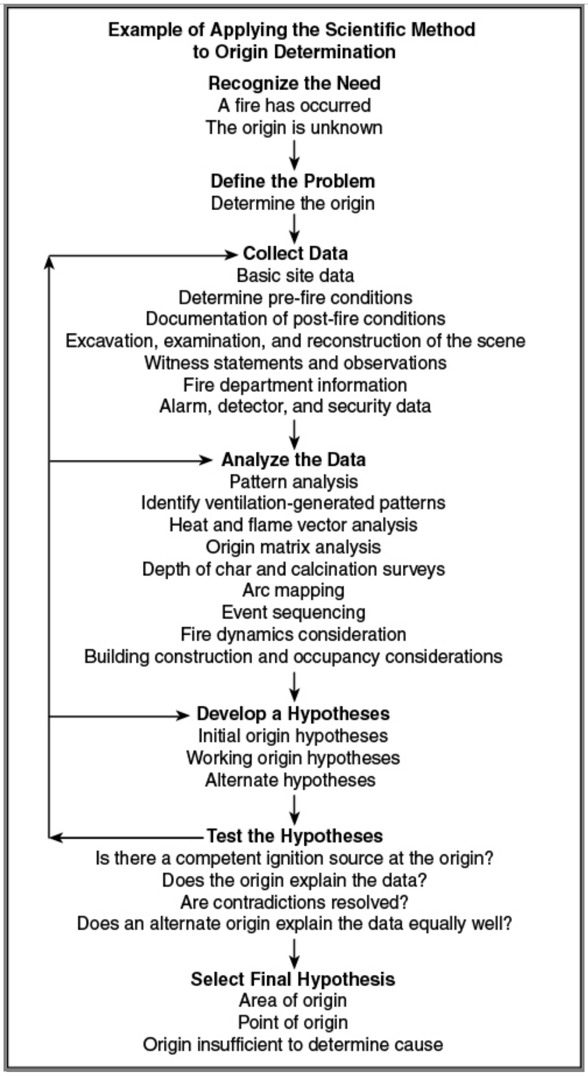
Response Message:

Public Input No. 81-NFPA 921-2014 [Section No. 18.1.2]
Public Input No. 146-NFPA 921-2014 [Section No. 18.1.2]

First Revision No. 144-NFPA 921-2015 [Section No. 18.2 [Excluding any Sub-Sections]]

The overall methodology for determining the origin of the fire is the scientific method as described in Chapter 4. This methodology includes recognizing and defining the problem to be solved, collecting data, analyzing the data, developing 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 hypotheses should be considered "working hypotheses," which upon testing may be discarded, revised, or expanded in detail as new data is collected during the investigation and new analyses are applied. This process is repeated as new information becomes available. *(See Figure 18.2.)*

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



Supplemental Information

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Public Input No. 71-NFPA 921-2014 [Section No. 18.2 [Excluding any Sub-Sections]]

Public Input No. 72-NFPA 921-2014 [Section No. 18.2 [Excluding any Sub-Sections]]

First Revision No. 145-NFPA 921-2015 [Section No. 18.2.3]

18.2.3 Sequential Pattern Analysis.

The area of origin may be determined by examining the fire effects and fire patterns. The surfaces of the fire scene record all of the fire patterns generated during the lifetime of the event, from ignition through suppression, although these patterns may be altered, overwritten, or obliterated after they are produced. The key to determining the origin of a fire is to determine the sequence in which these patterns were produced. Investigators should strive to identify and collect sequential data and, once collected, organize the information into a sequential format. Sequential data not only indicates what happened, but the order in which it happened ~~, but the order in which it happened. Identifiable fire spread patterns should be traced back to an area or point of origin. Once the area of origin has been established, the investigator should be able to understand and explain the fire spread~~ . One of the most important factors in determining the sequence of pattern production is considering whether the pattern can be accounted for in terms of ventilation. A large area of clean burning located next to, or directly across the room from, an opening was probably created after full room involvement was achieved. As such, this pattern will offer little insight into the area of origin.

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18.3.1.6 Structure Interior.

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

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First Revision No. 132-NFPA 921-2015 [Section No. 18.3.2.1]

18.3.2.1 Scope of Excavation and Reconstruction.

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

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

Supplemental Information

File Name	Description
Staff_only_FR_132_Fig_18.3.2.1.JPG	1. New figure 18.3.2.1.

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First Revision No. 133-NFPA 921-2015 [Section No. 18.3.2.7]

18.3.2.7 Washing Floors.

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

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

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

Supplemental Information

File Name	Description
Staff_only_FR_133_Fig_18.3.2.7_a_.JPG	New figure 18.3.2.7(a).
Staff_only_FR_133_Fig_18.3.2.7_b_.JPG	New figure 18.3.2.7(b).

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
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Submittal Date: Mon Jun 01 11:58:53 EDT 2015

Committee Statement

Committee Statement: Inclusion of color images as examples.

Response Message:

First Revision No. 147-NFPA 921-2015 [New Section after 18.4.1.5]

18.4.1.6*

Every pattern 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.

Supplemental Information

File Name	Description
FR_147_A.18.4.1.6.docx	1.New annex A.18.4.1.6.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Submittal Date: Tue Jun 02 10:52:31 EDT 2015

Committee Statement

Committee Statement: The committee believes that the additional material clarifies the scientific information within the document.

Response Message:

A.18.4.1.6 For further information, see:

Cox, A., Origin Matrix Analysis: A Systematic Methodology for the Assessment and Interpretation of Compartment Fire Damage. Fire and Arson Investigator, July 2013.

First Revision No. 68-NFPA 921-2015 [Section No. 18.4.3 [Excluding any Sub-Sections]]

Analysis of the depth of charring is most reliable for evaluating fire spread, rather than for the establishment of specific burn times or intensity of heat from adjacent burning materials. By measuring the relative depth and extent of charring, the investigator may be able to determine what portions of a material or construction were exposed the longest to a heat source. The relative depth of char from point to point is the key to appropriate use of charring — locating the places where the damage was most severe due to exposure, ventilation, or fuel placement. The investigator may then deduce the direction of fire spread, with decreasing char depths being farther away from a heat source. Certain key variables affect the validity of depth of char pattern analysis. These factors include the following:

(1) Single versus multiple heat or fuel sources creating the char patterns being measured. Depth of char measurements may be useful in determining more than one fire or heat source.

(2) Comparison of char measurements, which should be done only for identical materials. It would not be valid to compare the depth of char from a wall stud to the depth of char of an adjacent wooden wall panel.

(3) Ventilation factors influencing the rate of burning. Wood can exhibit deeper charring when adjacent to a ventilation source or an opening where hot fire gases can escape.

(4) Consistency of measuring technique and method. Each comparable depth of char measurement should be made with the same tool and same technique~~.~~ *[~~See~~ see Figure 16.4.2(f)] .~~]~~* It is important that a consistent amount of pressure is applied with the probe every time it is employed.

(5) Suppression and/or overhaul efforts can modify or destroy char patterns typically used for this type of analysis.

Submitter Information Verification

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Committee Statement

Committee Statement: The committee believes that the additional wording better clarifies the technique.
Response Message:
Public Input No. 142-NFPA 921-2014 [Section No. 18.4.3 [Excluding any Sub-Sections]]

First Revision No. 69-NFPA 921-2015 [Section No. 18.4.4.2]

18.4.4.2* Measuring Depth of Calcination.

The technique for measuring and analyzing depth of calcination ~~can use a visual observation of cross-sections or~~ should be performed using a probe survey. The ~~visual method requires careful removal of small, full-thickness sections [minimum approximately 50 mm (2 in.) diameter] of walls or ceilings to observe and measure the thickness of the calcined layer. The~~ probe method requires that a survey of the depth of calcination be undertaken by inserting a probe device, such as illustrated in Figure 18.4.4.2(a) and Figure 18.4.4.2(b), into the gypsum wallboard within the room of interest. Based on experimental data, it is recommended that the probe have a blunt tip with no tapering shoulders. The cross-sectional surface area of the probe used should be relatively small. Cross-sectional areas used in experimental work have ranged in size from 1.9 to 3.1 mm$_2$ ^{2} (0.003 to 0.005 in.^{2}). The probe can be attached to a force gauge to ensure uniform pressure is applied at the probe tip during each measurement. The pressure required to reach the line of demarcation where calcined and virgin gypsum meet has been studied and values are generally consistent ranging from 800 to 900 g/mm^2 (1120 to 1270 psi). Care should be taken to use approximately the same insertion pressure for each measurement. Currently available data suggests that probe pressures in this range are appropriate for both regular 12.7 mm (0.5 in.) and fire-rated 15.875 mm (0.625 in.) gypsum wallboard. ~~When using this method the investigator should conduct the survey at regular lateral and vertical grid intervals along the surface of the involved wallboard, usually in increments of 0.3 m (1 ft) or less. Such surveys can be made on either wall or ceiling installations of wallboard.~~ For lightweight gypsum wallboard, which is becoming increasingly prevalent, less pressure should be used. When using this method the investigator should conduct the survey at regular lateral and vertical grid intervals along the surface of the involved wallboard, usually in increments of 0.3 m (1 ft) or less. Such surveys can be made on either wall or ceiling installations of wallboard. Some limited correlations between depth of calcination and total heat exposure have been developed that can be used to enhance the information obtained from a calcination depth survey.

Figure 18.4.4.2(a) Two Instruments That Can be Used to Measure the Depth of Calcination.

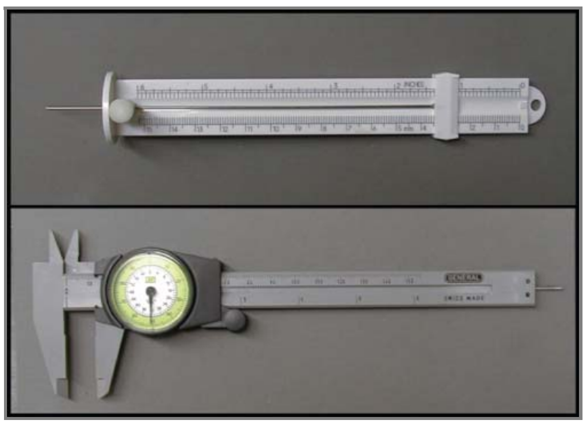
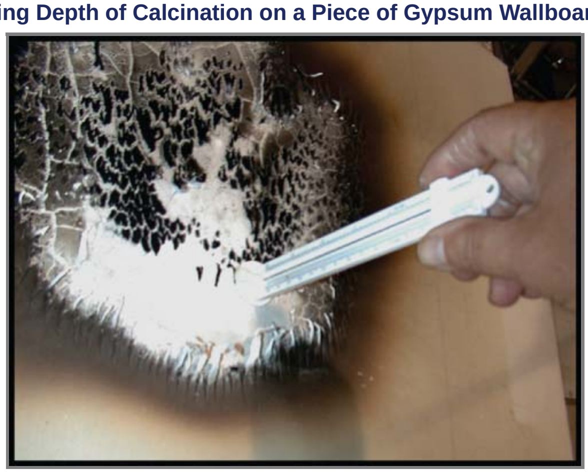


Figure 18.4.4.2(b) Measuring Depth of Calcination on a Piece of Gypsum Wallboard.



Submitter Information Verification

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Committee Statement

Committee Statement: The changes are based on current research and are used to update the document.

Response Message:

Public Input No. 291-NFPA 921-2015 [Section No. 18.4.4.2]
Public Input No. 312-NFPA 921-2015 [Section No. 18.4.4.2]

First Revision No. 70-NFPA 921-2015 [Section No. 18.4.5.6]

18.4.5.6 Arc Survey Limitations.

Arc surveys can identify areas where the fire had damaged energized electrical conductors ~~early~~ at some time in the fire's development. Likewise, the spatial relationship of arc sites can identify a specific space where the fire occurred before electrical energy to that space was cut off. Both of these investigative tools can be helpful in the origin determination. The accuracy of the effort, however, is directly dependent upon the investigator correctly identifying arc damage on the wires. Fire damage to copper conductors can mimic arc damage, and visual inspection at the fire scene site may not be sufficient to correctly identify validate arc sites. If the analysis of the circuits incorrectly identifies damage on the conductors as arcing, hypotheses formed from the analyses will be based on flawed data and will be incorrect. The investigator may want to collect each perceived arc site for more detailed evaluation and verification.

Submitter Information Verification

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Committee Statement

Committee Statement: The text clarifies the section.
Response Message:
Public Input No. 59-NFPA 921-2014 [Section No. 18.4.5.6]

First Revision No. 148-NFPA 921-2015 [Section No. 18.4.7]

18.4.7 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.

18.4.7.1*

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.

18.4.7.2*

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.

18.4.8* Origin Matrix Analysis.

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 .)*

Supplemental Information

File Name	Description
FR_148_A.18.4.7.1_2_A.18.4.8.1.docx	1. New annex A.18.4.7.1, A.18.4.7.2 & A.18.4.8.1.

Submitter Information Verification

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Submittal Date: Tue Jun 02 11:28:10 EDT 2015

Committee Statement

Committee Statement: The committee believes that the additional material clarifies the scientific information within the document.

[Staff Note: Proposed figure 18.4.8.1 and the proposed text surrounding figure 18.4.8.1 have been removed from ballot (First Revision No. 148). The appropriate permissions could not be attained from the copyright holder. If permissions are received, the committee can still consider it at the Second Draft Meeting.]

Response Message:

Public Input No. 212-NFPA 921-2014 [New Section after A.17.5.4.7.4]

A.18.4.7.1 For further information, see:

Carmen, Steven W., “Improving the Understanding of Post-Flashover Fire Behavior,” ISFI Proceedings 2008, International Symposium on Fire Investigation Science and Technology, National Association of Fire Investigators, Sarasota, FL, 2008, p.221.

Shanley, James H., P.E., USFA Fire Burn Pattern Tests, Report of the United States Fire Administration Program for the Study of Burn Patterns , Federal Emergency Management Agency, United States Fire Administration, Document No.: FA 178, 7/97, 1997

A.18.4.7.2 For further information, see:

Cox, A., Origin Matrix Analysis: A Systematic Methodology for the Assessment and Interpretation of Compartment Fire Damage. Fire and Arson Investigator, July 2013.

A.18.4.8.1 For additional information, see:

Carman, S.W., “Investigation of an Elevated Fire --Perspectives On The ‘Z-Factor’

Claflin, P. (2014). Effects of Multiple Ventilation Openings on a Post-Flashover Compartment Fire. Fire and Arson Investigator, Volume 64, Issue 3, pp. 16-25

First Revision No. 71-NFPA 921-2015 [Section No. 18.6.1 [Excluding any Sub-Sections]]

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.

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Committee Statement

Committee Statement: The additional word "uniquely" adds continuity throughout the document.

Response Message:

Public Input No. 136-NFPA 921-2014 [Section No. 18.6.1 [Excluding any Sub-Sections]]

First Revision No. 72-NFPA 921-2015 [Section No. 19.4.4.2.1]

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 ~~(a competent fuel);~~

(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 Appliance chapter for additional discussion)*~~ ; *(see Chapter 26)*

(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 ~~which~~ 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.

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Committee Statement

Committee Statement: The requested change to (7) improves the information provided within the guide. Also, the deletion of “a competent fuel” clarifies the information within the document. Fuel, relative to fire, is by definition something capable of burning, and thus the adjective “competent” is not necessary.

[Staff Note: The TC moved two changes to section 19.4.4.2.1, these have been combined into First Revision No. 72. Unless a ballotable detail is moved we can only have one revision per section.]

Response Message:

Public Input No. 215-NFPA 921-2014 [Section No. 19.4.4.2.1]

Public Input No. 149-NFPA 921-2014 [Section No. 19.4.4.2.1]

First Revision No. 75-NFPA 921-2015 [Section No. 19.6 [Excluding any Sub-Sections]]

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

Submitter Information Verification

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Submittal Date: Sun May 31 10:59:45 EDT 2015

Committee Statement

Committee Statement: The insertion clarifies the text.
Response Message:

First Revision No. 73-NFPA 921-2015 [Section No. 19.6.5 [Excluding any Sub-Sections]]

The process of elimination is an integral part of the scientific method. ~~Alternative~~ All potential ignition sources present, or believed to be present in the area of origin should be identified and alternative hypotheses should be considered and challenged against the facts. Elimination of a testable hypothesis by disproving the hypothesis with reliable evidence is a fundamental part of the scientific method. However, the process of elimination can be used inappropriately. ~~The process of determining~~ Identifying the ignition source for a fire ~~the ignition source for a fire, by eliminating~~ by believing to have eliminated all ignition sources found, known, ~~all ignition sources found, known, or believed~~ or suspected to have been present in the area of origin, and ~~then claiming such methodology is proof of an ignition source~~ for which ~~there is~~ no supporting evidence ~~of its existence~~ exists , is referred to by some investigators as *negative corpus*. Determination of the ignition source must be based on data or logical inferences drawn from that data. Negative corpus has typically been used in classifying fires as incendiary, although the process has also been used to characterize fires classified as accidental. ~~This~~ The negative corpus process is not consistent with the scientific method, is inappropriate, and should not be used because it generates untestable hypotheses, and may result in incorrect determinations of the ignition source and first fuel ignited. Any hypotheses formulated for the causal factors (e.g., first fuel, ignition source, and ignition sequence), must be based on the analysis of facts and logical inferences that flow from those facts . Those facts and logical inferences are derived from evidence, observations, calculations, experiments, and the laws of science. Speculative information cannot be included in the analysis.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Submittal Date: Sun May 31 10:45:28 EDT 2015

Committee Statement

Committee Statement: The committee has taken the input from 3 submitters and has developed wording to further clarify the text.

Response Message:

Public Input No. 78-NFPA 921-2014 [Section No. 19.6.5 [Excluding any Sub-Sections]]
Public Input No. 271-NFPA 921-2015 [Section No. 19.6.5 [Excluding any Sub-Sections]]
Public Input No. 216-NFPA 921-2014 [Section No. 19.6.5 [Excluding any Sub-Sections]]

First Revision No. 76-NFPA 921-2015 [Section No. 20.1 [Excluding any Sub-Sections]]

Determining the cause of a fire and classifying the cause of the fire are two separate processes that should not be confused with each other. Classification of a fire cause may be used for assignment of responsibility, reporting purposes, or compilation of statistics. Different jurisdictions may have alternative definitions that should be applied as required. The cause of a fire may be classified as accidental, natural, incendiary, or undetermined. Use of the term *suspicious* is not an accurate description for the classification of a fire cause. Suspicion refers to a level of proof, or level of certainty, and is not a classification for a fire cause. Suspicion is not an acceptable level of proof for making a determination of cause within the scope of this guide and should be avoided. Fires in which the level of certainty is possible or suspected, or in which there is only suspicion of that cause, should be classified as undetermined.

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Submitter Full Name: Michael Wixted
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Submittal Date: Sun May 31 11:04:12 EDT 2015

Committee Statement

Committee Statement: This provides clarification as to the statement addressing specifically the classification and not the cause of the fire.

Response Message:

Public Input No. 107-NFPA 921-2014 [Section No. 20.1 [Excluding any Sub-Sections]]

First Revision No. 77-NFPA 921-2015 [Section No. 20.1.4]

20.1.4 Undetermined Fire Cause.

Whenever the cause cannot be proven to an acceptable level of certainty, the proper classification is undetermined ~~as follows:~~ *(see 4.5)* .

(A)

Undetermined fire causes include those fires that have not yet been investigated or those that have been investigated, or are under investigation, and have insufficient information to classify further. However, the fire might still be under investigation and the cause may be determined later with the introduction or discovery of new information.

(B)

In the instance in which the investigator fails to identify the ignition source, the fire need not always be classified as undetermined. ~~If~~ For example, if the evidence ~~established~~ establishes one factor, such as the use of an accelerant, that evidence may be sufficient to establish an incendiary fire cause classification even where other factors, such as ignition source, cannot be identified.

Submitter Information Verification

Submitter Full Name: Michael Wixted

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Committee Statement

Committee Statement: The proposed changes to the text add clarification to the document.

Response Message:

Public Input No. 118-NFPA 921-2014 [Section No. 20.1.4]

Public Input No. 180-NFPA 921-2014 [Section No. 20.1.4]

Public Input No. 220-NFPA 921-2014 [Section No. 20.1.4]

First Revision No. 78-NFPA 921-2015 [Section No. 23.9.1.1]

23.9.1.1*

Dust explosions occur in a wide variety of materials, such as grain dusts; sawdust; carbonaceous materials, such as coal and charcoal; chemicals; drugs, such as aspirin and ascorbic acid (i.e., vitamin C); dyes and pigments; metals, such as aluminum, magnesium, and titanium; plastics; and resins, such as synthetic rubber. Published values of dust explosion properties should be used with caution, as the dust explosion properties of a specific dust can vary significantly based on the chemistry, composition, particle size, particle morphology, and moisture content. When specific properties of a dust are needed for an investigation, it is recommended to test samples of dust representative of the material involved in the incident, where possible.

Submitter Information Verification

Submitter Full Name: Michael Wixted
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Submittal Date: Sun May 31 11:22:27 EDT 2015

Committee Statement

Committee Statement: Providing additional information about potential differences between published values of dust explosion properties and the specific properties of a dust involved in an incident.

Response Message:

Public Input No. 210-NFPA 921-2014 [Global Input]

First Revision No. 79-NFPA 921-2015 [Section No. 23.9.2]

23.9.2* Particle Size.

~~Since~~ Because the combustion reaction takes place at the surface of the dust particle, the rates of pressure rise generated by combustion are largely dependent on the surface area of the dispersed dust particles. For a given mass of dust material, the total surface area, and, consequently, the ease of ignition and the violence of the explosion, increases as the particle size decreases. The finer the dust, the more violent is the explosion. ~~In general, an explosion hazard concentration of combustible dusts can exist when the~~ Figure 23.9.2(a) shows how the maximum explosion pressure, P_{max}, and maximum rate of pressure rise, $(dP/dt)_{max}$, vary with particle size for four different materials. Figure 23.9.2(b) shows how the minimum ignition energy of an agricultural dust varies with particle size. In general, a dust explosion hazard may exist when the oxidizable particles are 500 microns or less in diameter, and when fibers are 500 microns or less in their smallest dimension *(see NFPA 654)*. However, the specific particle size threshold where material is explosible is different for different materials as seen in Figure 23.9.2(a). Whether a dust can propagate an explosion can be evaluated by testing using methods such as ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.

Figure 23.9.2(a) Effect of Particle Size of Dusts on the Maximum Pressure and Maximum Rate of Pressure Rise.

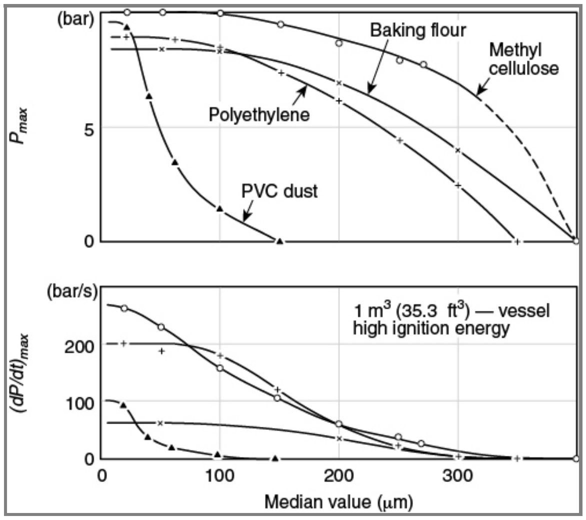
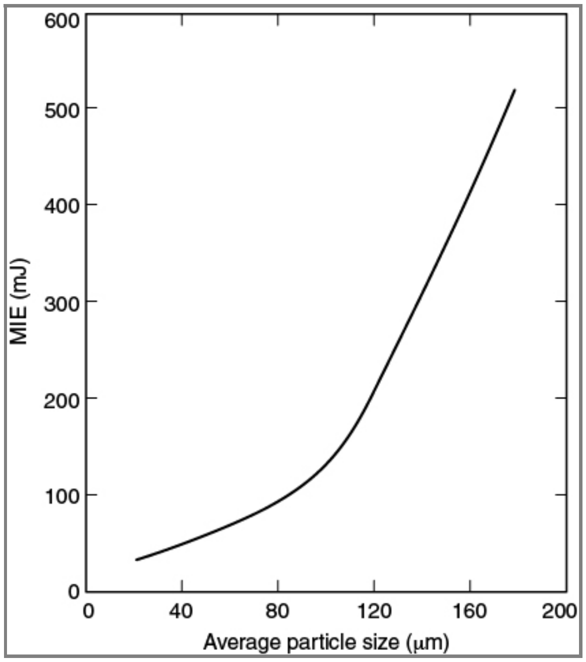


Figure 23.9.2(b) Effect of Average Particle Diameter of a Typical Agricultural Dust on the Minimum Ignition Energy.



23.9.2.1

There are some cases where certain particle sizes may exceed 500 microns and still present an explosion hazard. This is the case for some fibrous materials such as flock, which have very high length-to-diameter ratios.

Supplemental Information

File Name	Description
Staff_only_FR_79_Fig_23.9.2_a_b_.docx	1. New Figure 23.9.2(a) & (b).

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
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City:
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Submittal Date: Sun May 31 11:25:51 EDT 2015

Committee Statement

Committee Statement: Editorial changes were need and additional figures were added for clarity and consistency with NFPA 68.

Response Message:

Public Input No. 46-NFPA 921-2014 [Section No. 23.9.2 [Excluding any Sub-Sections]]

First Revision No. 80-NFPA 921-2015 [Section No. 23.9.3]

23.9.3* Concentration.

The concentration of the dust in air has a profound effect on its ignitibility and violence of the blast pressure wave. ~~As with ignitible vapors and gases, there are minimum explosive concentrations of specific dusts required for a propagating combustion reaction to occur. Minimum Explosive Concentrations (MEC) can vary with the specific dust from as low as 20 g/m^3 to 2000 g/m^3 (0.02 oz/ft^3 to 2 oz/ft^3) with the most common concentrations being less than 1000 g/m^3 (1 oz/ft^3). Particle size greatly influences minimum explosive concentration. Minimum concentration values vary widely depending upon the type of dust. The chemical reactivity of dust clouds is lower than that of gases, so MEC values necessarily have to be higher. Apart from exceptionally reactive gases MEC values are all greater than 30 gms/m^3, thus reported dust cloud MEC values that are lower are unreliable. Lacking more specific information a rough estimate can be made by multiplying reported Hartman Apparatus values by 2.~~ Similar to gases and vapors, the maximum explosion pressure (P_{max}) and rate of pressure rise $(dP/dt)_{max}$ occur when the dust concentration is at or close to the optimum mixture. Figure 23.9.3 shows the dependence of P_{max} and $(dP/dt)_{max}$ with dust concentration. P_{max} and $(dP/dt)_{max}$ (i.e., combustion rate) decrease if the mixture is fuel rich or fuel lean. P_{max} and $(dP/dt)_{max}$ are very low at the lower explosive limit and at very high fuel-rich concentrations.

Figure 23.9.3 Variation of Deflagration Pressure and Deflagration Index with Concentration for Several Dusts.

23.9.3.1

~~Unlike most gases and vapors, however, there is generally no reliable maximum limit of concentration. The reaction rate is controlled more by the surface-area-to-mass ratio than by a maximum concentration.~~ Analogous to the lower flammable limit (LFL) of ignitible vapors and gases, there are minimum explosible concentrations of specific dusts required for a propagating combustion reaction to occur. Minimum explosible concentrations (MECs) can vary with the specific dust from as low as 20 g/m^3 to 2000 g/m^3 (0.02 oz/ft^3 to 2 oz/ft^3) with the most common concentrations being less than 1000 g/m^3 (1 oz/ft^3). Particle size influences minimum explosible concentration. Minimum concentration values vary depending on the type of dust. The chemical reactivity of dust clouds is generally lower than that of gases, so MEC values necessarily have to be higher. The MEC of a specific dust can be determined using ASTM E1226, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*. There are general rules of thumb about the lack of visibility when a dust cloud is present at or above the MEC. For example, Eckhoff quotes others stating that a glowing 25-watt light bulb observed through 2 m of a coal dust cloud would not be visible at dust concentrations above 40 g/m^3 (see Eckhoff, *Dust Explosions in the Process Industries*).

23.9.3.2

~~Similar to gases and vapors, the rate of pressure rise and the maximum pressure that occur in the dust explosion are higher if the pre-explosion dust concentration is at or close to the optimum mixture. The combustion rate and maximum pressure decrease if the mixture is fuel rich or fuel lean. The rate of pressure rise and total explosion pressure are very low at the lower explosive limit and at very high fuel-rich concentrations.~~ Unlike the upper flammable limit (UFL) of gases and vapors, however, it is generally difficult to determine a maximum limit concentration for dusts. For some dusts the maximum explosion pressure and rate of pressure rise can still be substantial at dust cloud concentrations many times larger than the optimum concentration.

Supplemental Information

File Name	Description
Staff_only_FR_80_Fig_23.9.3.docx	1. New figure 23.9.3.

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
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Submittal Date: Sun May 31 11:54:24 EDT 2015

Committee Statement

Committee Statement: Editorial changes were need and an additional a figure was added for clarity and consistency with NFPA 68.

Response Message:

Public Input No. 50-NFPA 921-2014 [Section No. 23.9.3]

First Revision No. 81-NFPA 921-2015 [Section No. 23.9.4]

23.9.4 Turbulence in Dust Explosions.

Turbulence within the suspended dust–air mixture ~~greatly~~ increases the rate of combustion and thereby~~,~~ the rate of pressure rise. The shape and size of the confining vessel can have a profound effect on the severity of the dust explosion by affecting the degree of turbulence, such as the pouring of grain from a great height into ~~a largely~~ an empty storage bin. ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds* , a test method for measuring pressure rise and rate of pressure rise for combustible dust, is performed at a standardized turbulence level.

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Submittal Date: Sun May 31 12:30:36 EDT 2015

Committee Statement

Committee Statement: Reference to this test standard adds important information to this section.

Response Message:

Public Input No. 208-NFPA 921-2014 [Global Input]

First Revision No. 82-NFPA 921-2015 [Section No. 23.9.5]

23.9.5* Moisture.

~~Generally~~ In general , increasing the moisture content of the dust particles increases the minimum energy required for ignition and the ignition temperature of the dust suspension. The initial increase in ignition energy and temperature is ~~generally~~ low, but, as the limiting value of moisture concentration is approached, the rate of increase in ignition energy and temperature becomes high. Above the limiting values of moisture, suspensions of the dust will not ignite. However, there are some water-reactive materials, such as metals, that may be more reactive and burn more rapidly at moderate moisture contents than when dry. The moisture content of the surrounding air, however, has little effect on the propagation reaction once ignition has occurred.

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Committee Statement

Committee Statement: Adding information about metals. There are some metals that are more reactive when some moisture is present in the metal relative to when it is dry or very moist.

Response Message:

Public Input No. 51-NFPA 921-2014 [Section No. 23.9.5]

First Revision No. 83-NFPA 921-2015 [Section No. 23.9.6]

23.9.6 Minimum Temperature and Ignition Energy for Dust.

23.9.6.1

Dust explosions have been ignited by open flames, smoking materials, ~~light bulb~~ lightbulb filaments, welding and cutting, electric arcs, static electric discharges, friction sparks, heated surfaces, and spontaneous heating.

23.9.6.2

Ignition temperatures for most material dusts range from 320°C to 590°C (600°F to 1100°F). Layered dusts ~~generally~~ , in general have lower ignition temperatures than the same dusts suspended in air. ~~Minimum ignition energies are higher for dusts than for gas or vapor fuels and generally fall within the range of 10 mJ to 40 mJ, considerably higher than most flammable gases or vapors (~.02-.29 mJ).~~ The dust cloud ignition temperature can be measured using ASTM E1491, *Standard Test Method for Minimum Autoignition Temperature of Dust Clouds* . The dust layer ignition temperature can be measured using ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers* .

23.9.6.3

In general, minimum ignition energies (MIEs) are higher for dusts than for gas or vapor fuels and can extend to high energies. The lowest MIE report for dusts are in the 1 to 10 mJ range, higher than most flammable gases or vapors (~.02–..29 mJ). However, the ignition energy of dusts can be in orders of magnitude higher with some dusts having MIEs above 1J or 1 kJ. The MIE can be measured using ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air* .

Detail FR-159

23.9.6.4 Hybrid Dust Explosions.

The presence of flammable gases and vapors, even at concentrations less than the lower flammable limit (LFL) of the flammable gases and vapors, adds to the violence of a dust-air combustion. The resulting dust-vapor mixture is called a hybrid mixture and is discussed in Eckhoff, *Dust Explosions in the Process Industries* . In certain circumstances, hybrid mixtures can be deflagrable, even if the dust is below the MEC and the vapor is below the LFL. Furthermore, dusts determined to be nonignitible by weak ignition sources can sometimes be ignited when part of a hybrid mixture. An example of a hybrid mixture is a mixture of methane, coal dust, and air.

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Committee Statement

Committee Statement: The committee is making the text consistent with NFPA 68.

Response Message:

Public Input No. 52-NFPA 921-2014 [Section No. 23.9.6]
Public Input No. 209-NFPA 921-2014 [Global Input]

First Revision No. 88-NFPA 921-2015 [Section No. 24.2.4]

24.2.7.4* Exotic Accelerants.

Mixtures of fuels and Class 3 or Class 4 oxidizers *(see NFPA 430* may produce an exceedingly hot fire and may be used to start or accelerate a fire. Some of these oxidizers, depending on various conditions, can self ignite and will cause the same type of fire growth. Thermite mixtures also produce exceedingly hot fires. Such accelerants generally leave residues that may be visually or chemically identifiable. Presence of remains from the oxidizers does not in itself constitute an intentionally set fire. *(See 5.7.4.1.5.)*

24.2.7.4.1

Exotic accelerants have been hypothesized as having been used to start or accelerate some rapidly growing fires and were referred to in these particular instances as *high temperature accelerants (HTA)*. Indicators of exotic accelerants include an exceedingly rapid rate of fire growth, brilliant flares (particularly at the start of the fire), and melted steel or concrete. A study of 25 fires suspected of being associated with HTAs during the 1981–1991 period revealed that there was no conclusive scientific proof of the use of such HTA.

24.2.7.4.2

In any fire where the rate of fire growth is considered exceedingly rapid, other reasons for this should be considered in addition to the use of an accelerant, exotic or otherwise. These reasons include ventilation, fire suppression tactics, and the type and configuration of the fuels.

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Committee Statement

Committee Statement: The change moves present 24.2.4 Exotic Accelerants, and renumbers it to 24.2.7.4. This move improves the continuity of the subject material by placing it to follow the section on Presence of Ignitible liquids.

Response Message:

Public Input No. 181-NFPA 921-2014 [Section No. 24.2.4]

First Revision No. 89-NFPA 921-2015 [Section No. 24.2.7.1]

24.2.7.1 Examples of Incendiary Devices.

Examples of some incendiary devices, and the evidence that may establish their presence or use, are as follows:

(1) Books of paper matches and cigarettes from which the striker from the matchbook, cigarette filters, remaining cigarette ash, and the combustible materials ignited by the matches or cigarettes may be found in the area of origin

(2) Candles from which their wax and the remains of any combustible material ignited by the candles may be found in the area of origin

(3) Wiring systems or electric heating appliances to initiate a fire ~~(~~ , which may be evidenced by indications of tampering or modification of the wiring system, by the movement or arrangement of heat-producing appliances to locations near combustible materials, or by evidence of combustible materials being placed on or near heat-producing appliances~~)~~

(4) Fire bombs, ~~commonly called~~ or Molotov cocktails ~~(~~ , which leave evidence in the form of the ignitible liquid, chemicals, or compounds used within them, the broken or intact containers, and wicks~~)~~ *[Figure 24.2.7.1]*

Figure 24.2.7.1 Remains of "Molotov Cocktail" or Fire Bomb.

(5) Paraffin wax–sawdust incendiary device ~~[~~ , which can be evidenced by remains of wax impregnated with sawdust (e.g., artificial fire logs)~~]~~

Supplemental Information

File Name	Description
Staff_only_FR_89_Fig_24.2.7.1.jpg	1. New figure 24.2.7.1.

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Committee Statement

Committee Statement: The photo selected illustrates 24.2.7.1 (4) Fire Bombs. Other submitted photos offer no further illustration to the reader.

Response Message:

Public Input No. 238-NFPA 921-2015 [Section No. 24.2.7.1]

Public Input No. 239-NFPA 921-2015 [Section No. 24.2.7.1]
Public Input No. 240-NFPA 921-2015 [Section No. 24.2.7.1]
Public Input No. 241-NFPA 921-2015 [Section No. 24.2.7.1]

First Revision No. 91-NFPA 921-2015 [New Section after 24.3.1]

24.3.2 Forced Entry.

Evidence of forced entry may be discovered by the investigator. Broken door locks, windows, and other points of entry should be documented and examined for potential physical evidence. The investigator is cautioned that first responders and suppression personnel may force entry as part of their response to the fire. Forced entry may be evidence of burglary. It may also be staged by the owner or occupant in an attempt to mislead investigators.

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Committee Statement

Committee Statement: This section of the document addresses “Potential Indicators Not Directly Related to Combustion”. The discovery of forced entry to a fire damaged building is an important factor in this consideration. The statement instructs the investigator to document and check for potential physical evidence to recover. The statement also cautions the investigator of the potential for forced entry to be caused by responder to the fire.

Response Message:

Public Input No. 9-NFPA 921-2014 [New Section after 24.3.1]

First Revision No. 90-NFPA 921-2015 [Section No. 24.3.3.2]

24.3.4.2 Removal.

Fire scenes or fire buildings that are devoid of the "normal" contents reasonably expected ~~(~~ , or identified through witness statements, ~~etc.)~~ to be in the structure prior to the fire should be investigated and explained. ~~The~~ In general, the items removed are ~~generally~~ valuable items, such as ~~television sets, VCRs, stereo systems, computers~~ audiovisual equipment, personal electronics , camera equipment, stock, ~~or~~ equipment, or items that are difficult to replace, including files, business records, and so forth. Other items that may be removed prior to a fire may be those incriminating to a firesetter.

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Committee Statement

Committee Statement: The changes remove dated terminology from the document and replace it with current terms.
Response Message:

Public Input No. 8-NFPA 921-2014 [Section No. 24.3.3.2]

First Revision No. 92-NFPA 921-2015 [Section No. 25.5.5 [Excluding any Sub-Sections]]

As soon as conditions permit, photographic documentation of the body or body parts and their surroundings should be carried out. Video recordings ~~or instant-photo films~~ alone may not provide adequate detail but may be used as a supplement. If the body has to be moved due to emergency considerations, a few photographs may make the difference between a successful investigation and failure. Fire patterns or blast effects on clothing and on the body may be important evidence. Photographs should be taken of all exposed surfaces of the body before debris is disturbed, and again during examination and layering operations. The body should be photographed while it is being moved, to record any changes incurred during the removal process. In this situation, supplemental ~~videotaping~~ video documentation may be beneficial. The body should also be photographed once inside the body bag. After the body is removed, the location where it was found should be photographed. Clothing on the body is best collected at the ~~post scene~~ post-scene examination of the body, preferably at autopsy. If clothing on the body needs to be collected at the scene to preserve evidence, such as possible presence of ~~ignitable~~ ignitible liquid, photographs should be taken of the body before it is unclothed~~,~~ as well as~~,~~ after the removal of clothing.

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Committee Statement

Committee Statement: Removes wording of a photographic technology that is not longer current.
Response Message:
Public Input No. 10-NFPA 921-2014 [Section No. 25.5.5 [Excluding any Sub-Sections]]

First Revision No. 134-NFPA 921-2015 [Section No. 25.9.3]

25.9.3 X-ray Examination.

Current pathological analysis techniques, such as x-rays, can reveal information about the victim that is not obvious during a simple visual examination. X-rays made of the entire body and all associated debris can be ~~extremely~~ beneficial. The x-ray examination may detect the presence of foreign objects in or on the body such as bullets, knife tips, and explosive device components. These can be supplemented with dental x-rays and detailed x-rays of anatomic features (e.g., broken bones, wounds, ~~etc.~~ and so forth). Depending on the jurisdiction, x-rays may not be routinely conducted on victims; therefore, it may be necessary to request this procedure. *[See Figure 25.9.3(a) and Figure 25.9.3(b) .]*

Figure 25.9.3(a) X-ray with Bullet in Pelvis.

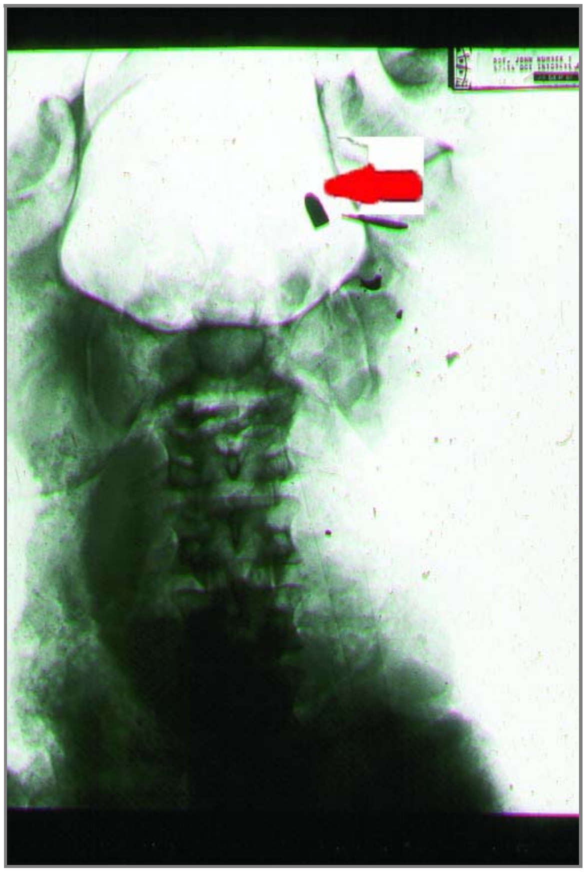
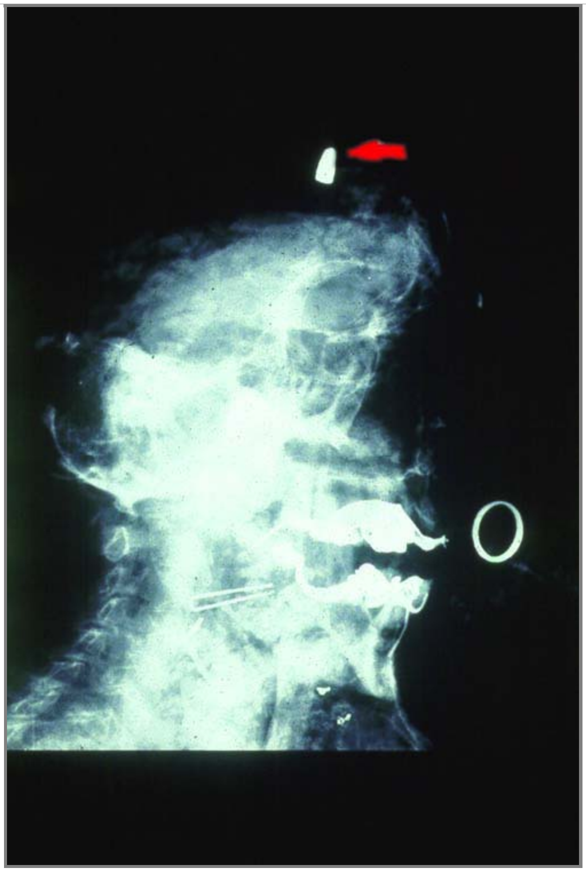


Figure 25.9.3(b) X-ray Shows Bullet in Top of Brain Cavity.



Supplemental Information

File Name	Description
Staff_only_FR_134_Fig_25.9.3_a_.tif	1. New figure 25.9.3(a).
Staff_only_FR_134_Fig_25.9.3_b_.bmp	2. New figure 25.9.3(b).

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Committee Statement

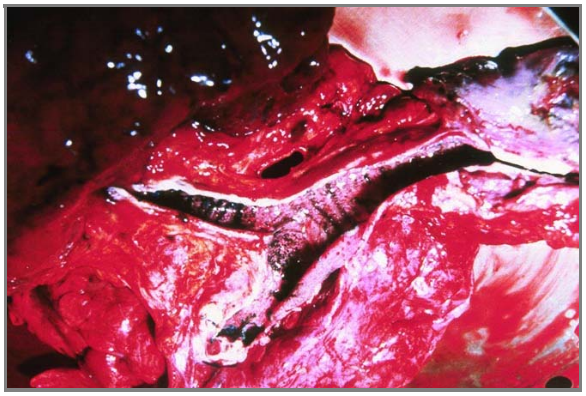
Committee Statement: Inclusion of color images as examples.
Response Message:

First Revision No. 135-NFPA 921-2015 [Section No. 25.9.7]

25.9.7 Smoke and Soot Exposure.

Evidence of smoke or soot in the lungs, bronchi, and trachea ~~(even esophagus)~~ , or even the esophagus is one of the most significant factors in confirming that the victim was alive and breathing smoke during the fire. This finding requires that the trachea be transected over its entire length. Soot in mouth or nasal openings alone may be the result of soot settling in openings and not from breathing. ~~Additionally~~ In addition , knowing the position of the body when found may be critical to a correct interpretation of soot in the airways. Soot may also be swallowed and found in the esophagus and stomach. The investigator should request that a full autopsy be performed on all fire victims to establish these fact patterns. Depending on the rapidity of the exposure to the toxicants in the smoke, victims may have vomited or may have foam emanating from their mouth due to edema in the lungs. *(See Figure 25.9.7 .)*

Figure 25.9.7 Soot in the Airway, or Trachea.



Supplemental Information

File Name	Description
Staff_only_FR_135_Fig_25.9.7.jpg	1. New figure 25.9.7.

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Submitter Full Name: Michael Wixted
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Submittal Date: Mon Jun 01 16:52:33 EDT 2015

Committee Statement

Committee Statement: Inclusion of color image as an example.
Response Message:

First Revision No. 93-NFPA 921-2015 [Section No. 25.10.3]

25.10.3 Pre-Fire Victim Impairment.

~~Both alcohol~~ Alcohol and ~~drugs (~~ prescription and illegal~~)~~ drugs can lead to impairment of a victim. The impairment can decrease the response to fire indicators such as smoke, noise, flames, or alarm activation resulting in delayed or no notification of the adverse conditions. Refer to the toxicology report for pertinent information regarding alcohol and drugs. The toxicological report may report the blood alcohol content (BAC) in % ethanol or g/dL ethanol. As a reference point, 0.08 g/dL is considered by some states to indicate that a driver is impaired, although studies have reported impairment to alcohol at even lower blood concentrations. The investigator should keep in mind that the effect of alcohol and drugs is additive with carbon monoxide (CO), hydrogen cyanide (HCN), and other fire gases so the total level of impairment may be due to a combination of pre-ignition and post-ignition effects.

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Committee Statement

Committee Statement: The committee believes that the additional sentence is helpful to the reader.

Response Message:

Public Input No. 161-NFPA 921-2014 [Section No. 25.10.3]

First Revision No. 94-NFPA 921-2015 [Section No. 26.2.3]

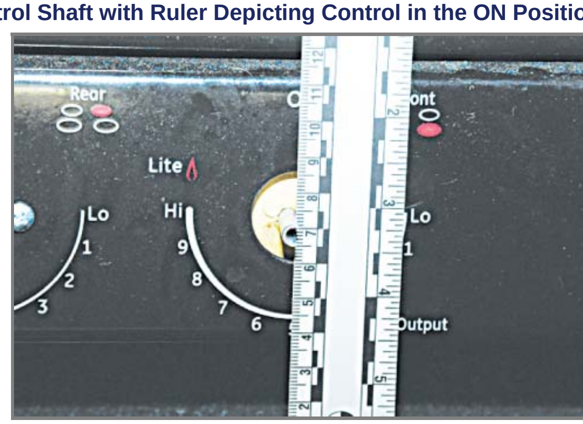
26.2.3 Positions of Appliance Controls.

Special attention in the photography and diagramming should be paid to the position of all controls (e.g., dials, switches, power settings, thermostat setting, valve position), position of movable parts (e.g., doors, vents), analog clock hand position, power supply (e.g., battery and ac house current), fuel supply, and any other item that would affect the operation of the appliance or indicate its condition at the time of the fire. *[See ~~Figure~~ Figure 26.2.3(a) through Figure 26.2.3(c).]*

Figure 26.2.3(a) Overall View of ~~the~~ a Gas Stove Depicting the Control Shafts ~~Positions~~ in Different Positions.

Figure 26.2.3(b) Gas Control Shafts in the OFF Position.

Figure 26.2.3(c) Gas Control Shaft with Ruler Depicting Control in the ON Position.



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Committee Statement

Committee Statement: New wording improves clarity.

Response Message:

Public Input No. 277-NFPA 921-2015 [Section No. 26.2.3]

First Revision No. 136-NFPA 921-2015 [Section No. 26.3.2]

26.3.2 Fire Patterns.

Fire patterns should be used carefully in establishing an appliance at the point of origin. Definite and unambiguous fire patterns help to show that the appliance was at the point of origin. Other causes of these patterns should be eliminated. The degree of damage to the appliance may or may not be an adequate indication of origin. Where the overall relative damage to the scene is light to moderate and the damage to the appliance is severe, then this may be an indicator of the origin. However, if there is widespread severe damage, other causes such as drop down, fuel load (i.e., fuel gas leak), ventilation, and other effects should be considered and eliminated. If the degree of damage to the appliance is not appreciably greater than the rest of the fire origin, then the appliance should not be chosen solely by virtue of its presence. *[See Figure 26.3.2(a) , Figure 26.3.2(b) and Figure 26.3.2(c) .]*

Figure 26.3.2(a) Overall View of the Stove with Fire Patterns Displayed on Left Side — Stove Top Raised Post Incident.

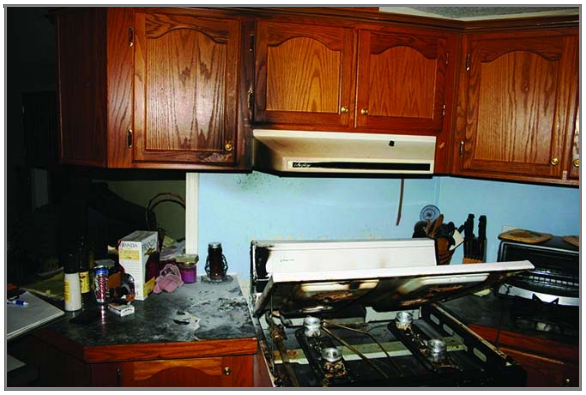
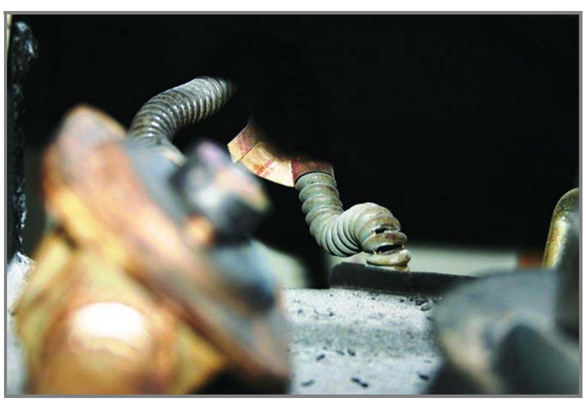


Figure 26.3.2(b) Overall View of the Stove and Counter Top Displaying Fire Pattern.

Figure 26.3.2(c) Overall View of the Gas Supply Line Inside Rear Portion of Stove with a Fire Pattern from the Right Side.



Supplemental Information

File Name	Description
Staff_only_FR_136_Fig_26.3.2_a_.JPG	1. New figure 26.3.2(a).
Staff_only_FR_136_Fig_26.3.2_b_.JPG	2. New figure 26.3.2(c).
Staff_only_FR_136_Fig_26.3.2_c_.JPG	3. New figure 26.3.2(c).

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Committee Statement

Committee Statement: Inclusion of color images as examples.

Response Message:

First Revision No. 95-NFPA 921-2015 [Section No. 26.5.2.3]

26.5.2.3 Batteries.

Batteries are used for a wide variety of applications, including stationary and portable appliances and some security devices. Batteries can range from car batteries to common dry cells to small button batteries for cameras and watches. Batteries provide about 1.5 V of direct current. Batteries of 6 V or 9 V are actually made of four or six dry cells, respectively, in one package. Remains . There are two types of batteries — primary and secondary. Primary batteries are discharged once and reach end of life, whereas secondary batteries can be discharged and recharged repeatedly. Batteries are produced in a variety of chemistries, each with their advantages and disadvantages. Some battery chemistries are better suited for certain applications than others. Batteries are produced in a wide variety of designs and form factors, for example, battery cells can be interconnected in series or parallel combinations to create a battery pack, which is housed in an enclosure that acts as a single unit. Depending on the chemistry and the materials used in the battery, remains of batteries that were present in an appliance can usually may be found after a fire. They usually will may be too damaged too much to indicate whether they provided power for ignition. However, what they were connected to could be important. One A battery can provide enough power to ignite some materials under certain conditions. In However, in most battery-powered devices, though, the normal circuitry will circuitry and/or safety mechanisms should prevent the energy of the battery from being sufficiently concentrated enough at one spot at one time to achieve ignition.

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Committee Statement

Committee Statement: Although the added material clarifies the text, the submitter should reference how the supporting material substantiates the new text. The submitter should also provide permissions from the authors/publishers of the supporting material to allow committee review.

Response Message:

Public Input No. 235-NFPA 921-2015 [Section No. 26.5.2.3]

First Revision No. 96-NFPA 921-2015 [Section No. 27.2.2]

27.2.2

Undeployed ~~airbags (~~ supplemental restraint systems (i.e., airbags) may pose a serious potential safety concern for fire investigators. ~~Sodium azide, the~~ The expelling agent for ~~the~~ airbags ~~in older-model vehicles,~~ is a hazardous material, and contact or inhalation can constitute a potential health hazard for the investigator. ~~Due to the increased installation of airbags, some vehicles come~~ Some vehicles may be equipped with multiple ~~airbags and~~ reactive occupant-restraint systems (i.e., airbags) . The investigator ~~will need to~~ should identify the systems that are present, the operational condition of those systems, and, if necessary, render those systems safe prior to disturbing the vehicle~~, in order~~ to prevent accidental operation. The investigator should be aware that even static charges may deploy an airbag.

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Committee Statement

Committee Statement: This change is primarily editorial in nature and serves to correct and clarify original text.

Response Message:

Public Input No. 37-NFPA 921-2014 [Section No. 27.2.2]

First Revision No. 97-NFPA 921-2015 [Section No. 27.3.1 [Excluding any Sub-Sections]]

Ignitible liquids are used in motor vehicles and can be associated with vehicle fires. These liquids may come in contact with an ignition source as a result of a malfunction of one of the vehicle systems, crash damage to one or more of the vehicle systems containing these liquids, or an incendiary act. Table 27.3.1 shows selected physical and fire properties of ignitible liquids used in motor vehicles. Whether a given liquid can ignite depends on the properties of the liquid, its physical state, the nature of the ignition source, and other variables related to the vehicle. The values of flash point and autoignition temperature in Table 27.3.1 were obtained in controlled laboratory tests, and are generally not applicable directly to ignition of these liquids in motor vehicles. The vehicle and the environment affect the surface temperature required to reach the autoignition temperature in a motor vehicle. These variables include airflow, the duration of contact between the liquid and the heated surface, and the material composition, mass, shape, and surface texture of the heated surface among others. Autoignition of a liquid in contact with a heated surface generally requires a temperature substantially greater than published laboratory autoignition temperatures of that liquid.

Table 27.3.1 Properties of Ignitible Liquids

	Flash Point [a]		Autoignition Temperature [b]		Flammability Limits [c]		Boiling Point [d]				Vapor Density[e]
					LFL	UFL	IBP		FPB		
Liquid	°C	°F	°C	°F	%	%	°C	°F	°C	°F	(Air = 1)
Gasoline	-45 to -40	-49 to -40	~~257–280~~ 350–460	~~495–536~~ 660–860	1.4	7.6	26–49	78–120	171–233	339–452	3–4
Diesel fuel (fuel oil #2)	38–62	100–145	254–260	489–500	0.4	7	127–232	260–450	357–404	675–760	5–6
Brake fluid	110–171	230–340	300–319	572–606	1.2	8.5	232–288	111–142	460–550	238–288	5–6
Power steering fluid	175–180	347–356	360–>382	680–>720	1	7	309–348	588–658	507–523	945–973	>1
Motor oil	200–280	392–536	340–360	644–680	1	7	299–333	570–631	472–513	882–955	>1
Gear oil	150–270	302–510	>382	>716	1	7	316–371	601–700	>525	>977	>1
Automatic transmission fluid	150–280	302–536	330–>382	626–>716	1	7	239–242	462–468	507–523	945–973	>1
Ethylene glycol (antifreeze)	110–127	230–261	398–410	748–770	3.2	15.3	196–198	385–388			2.1
Propylene glycol (antifreeze)	93–107	199–225	371–421	700–790	2.6	12.5	187–188	369–370			2.6
Methanol (washer fluid)	11–15	52–-55	464–484	867–903	6	36	65	149			1.1

[a]Flash point data was obtained from ~~Technical Data Sheets and Material Safety Data Sheets~~ technical data sheets and material safety data sheets from manufacturers and suppliers of the major brands of each type of fluid available in the United States. The flash points of gasolines reported in these sources were determined by ASTM D56, *Standard Test Method for Flash Point by Tag Closed Tester* . The flash points for diesel fuels, brake fluids, power steering fluids, motor oils, transmission fluids, gear oils, ethylene glycol (antifreeze), propylene glycol (antifreeze), and methanol were determined by ASTM D56, ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester* , or ASTM D93, *Standard Test Method for Flash Point by Pensky-Martens Closed Cup Tester* .

[b]Autoignition temperature data for gasoline, diesel fuel, brake fluid, ethylene glycol, propylene glycol, and methanol was obtained from ~~Technical Data Sheets and Material Safety Data Sheets~~ technical data sheets and material safety data sheets from manufacturers and suppliers of the major brands of each type of fluid available in the United States. These sources generally did not report the test method used to determine autoignition temperature; however, ASTM ~~E 659~~ E659, *Standard Test Method for Autoignition Temperature of Liquid Chemicals* , is the laboratory test method typically used to determine autoignition temperature. Autoignition temperature data for power steering fluid, motor oil, gear oil, and automatic transmission fluid were obtained using ASTM E659.

[c]Flammability limit data was obtained from ~~Technical Data Sheets and Material Safety Data Sheets~~ technical data sheets and material safety data sheets from manufacturers and suppliers of the major brands of each in the United States. These sources generally did not specify the laboratory test method used to determine the reported

flammability limits; however, ASTM E681, *Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gasses)*, is a laboratory test method typically used to determine the Lower Flammability Limit lower flammability limit (LFL) and the Upper Flammability Limit upper flammability limit (UFL).

[d]Boiling range data for gasolines was obtained from the Alliance of Automobile Manufacturers annual North American survey of gasoline properties for 2003. The boiling ranges reported in this survey were determined by ASTM D86, *Standard Test Method for Distillation of Petroleum*. Boiling range data for diesel fuel was obtained from Technical Data Sheets and Material Safety Data Sheets technical data sheets and material safety data sheets from manufacturers and suppliers of the major brands of diesel fuel in the Unites States. These sources generally did not report the laboratory test method used to determine the boiling range of diesel fuel. Boiling range data for brake fluid, power steering fluid, motor oil, gear oil, and automatic transmission fluid were determined by ASTM D2887, *Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography*. Boiling point data for ethylene glycol, propylene glycol, and methanol were obtained from Material Safety Data Sheets material safety data sheets from manufacturers and suppliers of these chemicals. These sources did not report the laboratory test method used to determine boiling point. In the table IBP and FBP are Initial Boiling Point and Final Boiling Point initial boiling point and final boiling point, respectively.

[e]Vapor density data was obtained from Material Safety Data Sheets material safety data sheets from manufacturers and suppliers of these materials.

Studies include the following:

1. API PUBL 2216, *Ignition Risk of Hydrocarbon Vapors by Hot Surfaces in the Open Air*.

1. 2. Arndt, S.M., Stevens, D.C., and Arndt, M.W., “The Motor Vehicle in the Post-Crash Environment, An Understanding of Ignition Properties of Spilled Fuels,” SAE 1999-01-0086, International Congress and Exposition, Detroit, MI, March 1–4, 1999.

2. LaPointe, N.R., Adams, C.T., and Washington, J, “Autoignition of Gasoline on Hot Surfaces” *Fire and Arson Investigator*, Oct. 2005: pp. 18–21.

3. Colwell, J.D. and Reze, A. “Hot Surface Ignition of Automotive and Aviation Fluids,” *Fire Technology*, Second Quarter 2005, pp. 105–123.

4. API PUBL 2216, *Ignition Risk of Hydrocarbon Vapors by Hot Surfaces in the Open Air* LaPointe, N.R., Adams, C.T., and Washington, J, “Autoignition of Gasoline on Hot Surfaces” *Fire and Arson Investigator*, Oct. 2005: pp. 18–21.

Supplemental Information

File Name	Description
Staff_only_FR_97_Table_27.3.1.docx	1. Changes to Table 27.3.1.

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First Revision No. 98-NFPA 921-2015 [Section No. 27.3.1.1]

27.3.1.1* Hot Surface Ignition.

The Some hot surfaces which exist in a motor vehicles may be of sufficient temperature to autoignite ignite ignitable ignitible liquids commonly found in these vehicles. This form of autoignition may be referred to temperature is known as hot surface ignition temperature, a form of autoignition temperature. Autoignition temperatures are determined by ASTM E659, *Standard Test Method for Autoignition Temperature of Liquid Chemicals* , which is a laboratory test procedure and utilizes a closed test environment . There is a difference between autoignition temperature, which is a property of a liquid temperatures determined through standard test methods, and hot surface ignition temperatures that are dependent on a number of underhood conditions including, but not limited to, the temperature, which is not a property of the hot surface; the residence time of the ignitible liquid on the hot surface; the temperature of the ignitible liquid; the physical state of the ignitible liquid; the surface characteristics of the hot surface; the geometry, size, and mass of the hot surface; and the airflow in the surrounding area where the ignitible liquid contacts the hot surface . Experimental testing has shown that hot surface ignition temperatures for common automotive liquids may be substantially higher than reported autoignition temperatures. For example one study shows that the hot surface ignition temperature of gasoline was 354°C (670°F) whereas the reported autoignition temperature range for gasoline as shown in Table 27.3.1 is 257–280°C (495–536°F). The study compared the autoignition temperatures, as derived from ASTM E659, and hot surface ignition temperatures, under test conditions using commercially available unleaded regular (CA ULR) gasoline.

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Public Input No. 298-NFPA 921-2015 [Section No. 27.3.1.1]

First Revision No. 99-NFPA 921-2015 [Section No. 27.4.1]

27.4.1 Open Flames.

The most common A source of an open flames in a vehicles is an exhaust intake system backfire out of the carburetor. Propagation will rarely occur is rare if the air cleaner is properly in place. However, modern vehicles use Another source of open flames is an after-fire from the exhaust system. Modern vehicles use computer-regulated fuel injection systems that eliminate the carburetor reduce such conditions . Lit matches and other smoking materials may ignite debris in the ashtray combustible materials , resulting in a fire. In recreational vehicles, appliance pilots or operating burners of ranges, ovens, water heaters furnaces, etc. and so forth are open-flame ignition sources.

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Public Input No. 204-NFPA 921-2014 [Section No. 27.4.1]

First Revision No. 100-NFPA 921-2015 [Section No. 27.4.2.4]

27.4.2.4 Electrical Short Circuits and Arcs (— Electric Discharge) .
Short circuits can result when the wiring conductor insulation becomes abraded, cut, brittle, fractured, or otherwise damaged, allowing it to contact a grounded surface. A shorted circuit, if not properly fused, can result in excess heating and arcing or electrical discharging. During an impact, shorts and arcs (i.e., electrical discharge) can be created as a result of the crushing, stretching, and cutting of wiring conductors. Aftermarket equipment, installed with inadequately protected, sized, or secured wiring, may present a short circuit risk. Some wiring conductors such as battery output and starter circuits are not overcurrent protected and carry very high amperage. An examination of the battery for indications of impact damage should also be performed.

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Public Input No. 187-NFPA 921-2014 [Section No. 27.4.2.4]

First Revision No. 101-NFPA 921-2015 [Section No. 27.4.2.5]

27.4.2.5* Arc (, Carbon) , Tracking.

An electrical potential applied across an insulating material can result in a short circuit by a phenomenon called arc tracking, (*see* 9.9.4.5) . The process occurs more quickly if the surface is contaminated with road salt or other conductive materials. The process can occur with 12-volt electrical or higher dc or 120-volt ac vehicle systems.

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Public Input No. 188-NFPA 921-2014 [Section No. 27.4.2.5]

First Revision No. 155-NFPA 921-2015 [Section No. 27.4.2.6]

27.4.2.6* Lamp Bulbs and Filaments.

Bulb surfaces can produce sufficient heat to ignite some combustible materials that may be in contact with them. Lamp filaments of broken bulbs can also be a source of ignition for some vapors, especially gasoline. Normally operating headlamp filaments have temperatures of approximately 1400°C (2550°F). However, most filaments operate in a vacuum or inert atmosphere. When the filament is exposed to ambient air, it will typically operate for only a few seconds, then burn open. Once the filament opens, the source of ignition is gone. When examining vehicle headlamps, the bulbs currently installed in the headlamp assembly should be inspected to determine if they are the correct size, type, and wattage that was recommended by the original equipment manufacturer (OEM). If an incorrect bulb type was installed, resistive heating at the connection point of the bulb and wiring could occur and cause a failure resulting in a fire. Also, if a bulb was installed that was of a higher wattage than the OEM bulb, the heating created by the bulb may be greater than the lamp assembly was rated to sustain. The heating caused by the greater wattage of the bulb could cause the lamp assembly to ignite.

Detail FR-156

27.4.2.6.1

Vehicles may be equipped by the OEM with high-intensity discharge (HID) headlamps. The xenon bulbs used in HID lighting systems produce three times the light output of standard halogen headlamps with less operating energy. HID headlamps require a high-voltage ignition source to start, up to 25,000 volts, but, depending on the system, only 40–90 volts to operate once the initial arc has formed. The normal 12 volts dc from the vehicle's electrical system is stepped up and controlled by an igniter module and inverter (ballast), which also converts the voltage to the necessary ac to operate the HID headlamps. The ballast then adjusts the voltage and current frequency to operating requirements. Aftermarket HID conversion kits are commonly available and, if installed, could overload the OEM wiring or cause other installation issues that could result in a fire within the headlight assembly.

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Public Input No. 279-NFPA 921-2015 [Section No. 27.4.2.6]

First Revision No. 103-NFPA 921-2015 [Section No. 27.4.2.7]

27.4.2.7 External Electrical Sources Used in Vehicles.

While most electrical sources in vehicles are contained within the vehicle, there are situations where external electrical power is supplied to the vehicle. Examples of these sources are electrical hook-ups used in recreational vehicles and trailers, electric block heaters for engines, vehicle interior heaters, and battery chargers. Many vehicles used in colder climates have ~~an~~ electric ~~block~~ heaters to warm the engine oil, ~~or coolant to~~ engine coolant, batteries, or transmissions to ease starting. This type of heater is typically a permanent installation on the vehicle and ~~will be~~ equipped with a power cord. Inspection of electrical power cords should be made when applicable, because an overload of, or damage to, the cord or a failure of the appliance could be the cause of the fire. Improper application of external electricity can damage vehicle components, resulting in failure, and possibly in fire. ~~Where~~ When recreational vehicles are connected to external power, the circuit wiring can be inspected for indications of ignition involvement.

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First Revision No. 105-NFPA 921-2015 [Section No. 27.4.3.1]

27.4.3.1*

Exhaust systems can generate ~~sufficiently~~ temperatures high ~~temperatures~~ enough to ignite combustible material, including ~~ignitable~~ ignitible liquids in the engine compartment. Automatic transmission fluid, particularly if heated due to an overloaded transmission, can ignite on a hot manifold. Engine oil and certain brake fluids (e.g., DOT 3 and 4) dropping on a hot manifold can also ignite. When a vehicle is suddenly brought to rest and shut off, the time for the exhaust manifold temperature to span 80 percent of the temperature difference between the initial temperatures and the ambient temperature is typically 20 to 30 minutes. While exhaust manifolds cool immediately when the vehicle is suddenly brought to rest and shut off, underbody catalytic converters generally experience a temperature increase lasting several minutes and then begin to cool. The time for underbody catalytic converters to span 80 percent of the temperature range from the steady-state temperature to ambient temperature typically ranges from 45 minutes to more than 90 minutes. If unburned fuel flows through the exhaust system, the catalytic converter temperatures can increase as ~~this~~ the fuel is oxidized within the catalytic ~~converters. Those fluids may ignite only~~ converter. Ignitible liquids in contact with exhaust system components may ignite shortly after the vehicle is shut off. This ignition is due to the loss of airflow through the engine compartment, which disperses these vapors and cools hot engine surfaces. In most vehicles, the pipe surface just upstream of the catalytic converter will operate hotter than the converter itself.

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First Revision No. 106-NFPA 921-2015 [Section No. 27.4.4]

27.4.4 Mechanical Sparks.

Metal-to-metal contact (e.g., steel, iron, or magnesium) or metal-to-road surface contact can create frictional contact sparks, with enough energy to ignite gases, vapors, and/or liquids that are in an atomized state. Metal-to-metal contact may occur at drive pulleys, drive shafts, or bearings, for example. Metal-to-road surface contact typically involves a broken component, such as a drive shaft, exhaust system, or wheel rim after the loss of a tire or in a crash. All metal-to-metal or metal-to-road surface sparking requires that the vehicle be running and/or in motion. Sparks generated at speeds as low as 8 kmh (5 mph) have been determined to reach temperatures of 800°C (1470°F) ~~(orange sparks)~~ . Higher speeds have produced ~~white~~ sparks in the 1200°C (2190°F) range. Aluminum-to-road surface sparks are not a competent ignition source for most materials because of the relatively low melting temperature of aluminum. The small particle size (i.e., mass) of sparks limits the quantity of energy available from them to ignite materials they contact. Also, sparks cool rapidly, especially when moving through air, which further limits the rate of heat transfer to materials they contact. For these reasons, it is difficult for sparks to ignite solid materials.

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First Revision No. 107-NFPA 921-2015 [Section No. 27.5.2.4.1]

27.5.2.4.1 Diesel Particulate Filters (DPFs).

~~Diesel particulate filters are~~ DPFs, diesel exhaust fluid (DEF) dosing, and selective catalytic reduction (SCR) systems are unique to diesel exhaust systems. The DPF is a device designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine. In addition to collecting the particulate, a method must exist to clean the filter. Some filters are single use disposable filters, while others are designed to burn off the accumulated particulate, referred to as regeneration. Regeneration can be passive~~, (through the use of~~ via a catalyst~~)~~ , or active, which may use an injected fuel to heat the filter to a temperature sufficient to burn carbon soot. In either case, high surface temperatures exist, creating an ignition hazard. Failure to maintain manufacturer-required shielding and clearance between these hot external surfaces and combustible materials may result in ignition of combustible materials. DEF valves provide a fine mist of DEF to be sprayed into the hot exhaust stream, and the SCR system reduces nitrogen oxide (NOx) levels by converting NOx into nitrogen gas and water vapor.

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First Revision No. 108-NFPA 921-2015 [Section No. 27.5.3.2]

27.5.3.2

In addition to providing electrical energy, the lead–acid battery can also be a source of fuel in the form of hydrogen gas. Hydrogen can be released during charging operations. Small amounts of hydrogen and oxygen are also present inside sealed (i.e., ~~no maintenance~~ no-maintenance) batteries and can be released due to mechanical damage during a collision. Hydrogen gas has a very wide explosive range and is easily ignited by low energy sources. However, it is unusual for a hot surface to cause hydrogen ignition. A release of hydrogen gas may occur from an internal battery failure. During such a condition, a significant amount of heat may be released, resulting in ignition of hydrogen gas, battery housing, or adjacent combustibles.

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Public Input No. 283-NFPA 921-2015 [Section No. 27.5.3.2]

First Revision No. 110-NFPA 921-2015 [New Section after 27.5.3.3.3]

27.5.3.3.4* Arc Mapping

Arc mapping has been researched and documented typically in post-flashover structural fires with properly fused, alternating current (ac) electrical circuits. Arc mapping may not be an effective technique for determining the origin of a fire in automobiles, trucks, buses, construction, agricultural, or other equipment that use direct current (dc) electrical circuits with a common ground circuit when analyzing secondary electrical circuits. Many of the electrical circuits in these products are routed together and often packaged in harnesses containing many different circuits and wires of many different gauges protected at different points by different levels of fuses, circuit breakers, fuse links, or are sometimes without over-current protection. When a fire destroys the insulating materials of powered circuits and components, all conductive materials of the vehicle or equipment are potentially available as alternate, inadvertent current paths, (including circuits routed adjacent to the powered circuits). Powered circuits can potentially energize alternative electrical paths and inadvertent current paths can be created, causing arcs and shorts, remote from, and unassociated with, the area of fire origin. Primary circuits with limited or no over-current protection in single conductor applications, may reveal evidence of electrical activity.

Supplemental Information

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Response Message:

Public Input No. 183-NFPA 921-2014 [New Section after 27.5.3]

Annex A Explanatory Material

Annex A is not a part of the recommendations of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.27.5.3.3.4 For information, see:

D. R. Stahl and K. D. Parrott, "Applicability and Limitations of Arc Mapping in Vehicle and Equipment Fire Investigation," Proceedings of International Symposium of Fire Investigation Science and Technology (ISFI 2012), University of Maryland, 15-17 October, 2012.

K. D. Parrott and D. R. Stahl, "Electrical Arcs and Sparks: A literature Review Of Definitions And Their Implications In The Analysis Of 12 Volt Direct Current Electrical System Fires, Proceedings of International Symposium of Fire Investigation Science and Technology (ISFI 2014), University of Maryland, 15-17 October, 2012.

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First Revision No. 109-NFPA 921-2015 [New Section after 27.5.3.5]

27.5.3.6 Engine Control Modules (ECMs).

Electronic ECMs, which are generally found on fleet trucks and buses, may record and store data regarding recent operation of the engine and vehicle. Many truck and bus fleets are connected through electronic communication systems to companies that maintain records regarding the truck's operation and deficiencies in the truck's systems. Monitoring agencies may be able to provide stored information that is unavailable from other sources after a fire.

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Public Input No. 193-NFPA 921-2014 [Section No. 27.5.3.5]

First Revision No. 111-NFPA 921-2015 [Section No. 27.5.4.4]

27.5.4.4 Electric Motors.

Vehicles such as pure electrics and hybrids (i.e., combination of internal ~~combustion-electric~~ combustion and electric) ~~will~~ have one or more high-power electric motors to provide or augment the torque to drive the vehicle. These motors ~~will be~~ are connected to power electronics, which in turn ~~will be~~ are powered by a battery or ~~ultra capacitors~~ ultra-capacitors . The power supply providing energy to the motor(s) may range up to 600 volts. ~~Initially, electric motors were~~ Electric motors may also be used in vehicles to provide steering assistance instead of hydraulic power steering systems. Conventional electric motors been designed for dc, but ~~the trend is toward~~ some manufacturers are trending toward variable frequency ac motors~~. However~~ ; however , small electric vehicles, such as golf carts, still operate on dc.

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Public Input No. 194-NFPA 921-2014 [Section No. 27.5.4.4]

First Revision No. 112-NFPA 921-2015 [Section No. 27.8.1 [Excluding any Sub-Sections]]

The examination of a motor vehicle after it has burned is a complex and varied task. As with structure fires, the first step is to determine an area of origin. ~~Most motor~~ Motor vehicles can ~~be divided into three major compartments~~ have five major areas : the exterior engine compartment, ~~the~~ passenger compartment or interior, cargo compartment, and the ~~cargo compartment~~ underbody or underchassis . The size, construction, and fuel load of these compartments can vary considerably. The use of vehicle inspection field notes *[see Figure A.16.3.2(h)]* may assist the investigator in recording information.

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Public Input No. 163-NFPA 921-2014 [Section No. 27.8.1 [Excluding any Sub-Sections]]

First Revision No. 113-NFPA 921-2015 [Section No. 27.14.1.5]

27.14.1.5

Because diesel vehicles often have large-capacity fuel tanks with 760 L (200 gal) of capacity or greater , a fire in a truck where fire suppression is delayed may involve all the fuel~~, causing~~ and cause severe damage. This often makes determination of the origin and cause of the fire more difficult. In cooler climates, many vehicles use programmable coolant heaters, fuel, and engine oil heaters. Cab/sleeper heaters that operate on diesel fuel are also available. These systems should be inspected for possible involvement in the fire cause.

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Public Input No. 184-NFPA 921-2014 [Section No. 27.14.1.5]

First Revision No. 115-NFPA 921-2015 [Section No. 27.14.6]

27.14.6 Agricultural Equipment.

Combines, cotton pickers, balers, ~~and~~ farm tractors, and other similar equipment have numerous hydraulic components with the potential for fluid leaks similar to other heavy equipment. Balers and cotton pickers can pick up items from the field that ~~might~~ may spark against ~~the~~ steel components, ~~while baling dry materials, thereby~~ igniting ~~the~~ dry harvesting materials. ~~No evidence~~ Evidence of the igniting substance ~~would~~ may not be found after the fire. Worn or unlubricated bearings can overheat, igniting combustible ~~accumulations~~ harvesting materials . Disassembly of the rollers after the fire should reveal the damaged bearing. Birds and small rodents can build nests in agricultural equipment when not in use and if located near the exhaust components, the nest can be ignited by the heat of the exhaust system when the equipment is later used. *(For more information on agricultural equipment fires, see Section 27.15 .)*

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First Revision No. 158-NFPA 921-2015 [Section No. 28.10.1.2]

28.10.1.2*

The weather can cause or contribute to hazards. Rain can create slippery footing. Lightning may be a concern as well. During lightning conditions, the investigator should not stand under trees, but rather move to open space, staying low without lying down.

Supplemental Information

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Committee Statement

Committee Statement: The addition of NFPA 780 as an Annex item provides a valuable resource for this document.

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Public Input No. 323-NFPA 921-2015 [New Section after A.28.8.2.3]
Public Input No. 322-NFPA 921-2015 [Section No. 28.10.1.2]

FR-158, new annex material

A.28.10.1.2

NFPA 780, Annex M provides additional information on personal safety from lightning.

First Revision No. 118-NFPA 921-2015 [Section No. 30.3.2]

30.3.2

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

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First Revision No. 119-NFPA 921-2015 [Section No. 30.4.1.2]

30.4.1.2* ~~High Pressure~~ High-Pressure /Marine Fuel Injection Systems ~~(~~ , Including Return Systems~~)~~ .

Fuel injection systems on inboard and I/O engines in boats generally include a throttle body, plenum and fuel rail assembly, knock sensor, and engine control module. The design of the system is unique to each marine engine manufacturer. In some instances, the fuel injection system for a particular model engine may have three or more different versions. It is important that the investigator record the engine serial number and contact the manufacturer to establish which system design is applicable. The fuel storage and delivery system onboard boats are low-pressure systems and the tank is vented. Gasoline-powered vessels built after August 1, 2012 must meet the EPA requirements for evaporative emissions. These vessels will have closed systems that may feature specialized fuel caps, vents, carbon canisters, relief valves, and diurnal controls.

30.4.1.3* Diesel.

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

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Response Message:

Public Input No. 23-NFPA 921-2014 [Sections 30.4.1.2, 30.4.1.3]

First Revision No. 120-NFPA 921-2015 [Section No. 30.4.7.1]

30.4.7.1

Permanently installed fuel tanks are vented from the top via a hose routed overboard and are equipped with a flame arrester. The ventilation of fuel tanks is mandated under 33 CFR 183.520~~, "Fuel tank vent systems."~~ . Additional information can be found in 5.6.10–5.6.12 of NFPA 302~~, *Fire Protection Standard for Pleasure and Commercial Motor Craft* ,~~ and ABYC H-24.13, *Gasoline Fuel Systems*. Gasoline-powered vessels built after August 1, 2012 must meet the EPA requirements for evaporative emissions. These vessels will have closed systems that may feature specialized fuel caps, vents, carbon canisters, relief valves, and diurnal controls.

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Sun May 31 16:54:40 EDT 2015

Committee Statement

Committee Statement: Adds important and current data to this chapter.
Response Message:
Public Input No. 24-NFPA 921-2014 [Section No. 30.4.7.1]

First Revision No. 121-NFPA 921-2015 [Section No. 30.4.9.5.2]

30.4.9.5.2*

Hydraulic thruster systems are available, ~~but~~ and are ~~not~~ generally used in larger boats. ~~Typically, thrusters are electrically driven motorized propellers located in a tunnel forward in the boat. These systems are generally 12 or 24 volts dc and utilize a 200 amp fuse installed near the thruster.~~

Submitter Information Verification

Submitter Full Name: Michael Wixted

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Sun May 31 16:56:39 EDT 2015

Committee Statement

Committee Statement: Hydraulic thrusters are generally found on larger vessels - 75 or larger. The statements about electrical thrusters are being moved from the hydraulic section to the electrical section in propulsion systems 30.7, see FR-122.

Response Message:

Public Input No. 26-NFPA 921-2014 [Section No. 30.4.9.5.2]

First Revision No. 122-NFPA 921-2015 [New Section after 30.7.1]

30.7.1.1 Bow and Stern Thrusters.

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

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Sun May 31 17:00:43 EDT 2015

Committee Statement

Committee Statement: Electric bow and stern thrusters have grown in popularity, particularly on smaller boats. It is uncommon to find a mid sized boat without at least a bow thruster. These devices draw a lot of electricity, many cases in the front of the boat, far from DC power. This is completing the work started in FR-121 of moving the applicable material.

Response Message:

Public Input No. 27-NFPA 921-2014 [New Section after 30.7.1]

First Revision No. 123-NFPA 921-2015 [Section No. 30.9 [Excluding any Sub-Sections]]

In general, the requirements for recording and documenting a boat fire incident are similar to those for structures and vehicles. Whenever possible, the boat should be examined in place at the scene. In many cases, however, the investigator may not have the opportunity to view the boat in place. For many reasons, the boat may have been moved before the investigator reaches the scene. Frequently, part of the documentation takes place at a salvage yard, repair facility, marina, boatyard, or warehouse. Title 33 CFR Part 173 Subpart C requires that a U.S. Coast Guard boating accident report (BAR) be completed following any incident where there was a fatality, an injury requiring medical treatment, damage to vessels in excess of $2000, or total loss. This information must be submitted to the U.S. Coast Guard and the state where the incident took place.

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Sun May 31 17:03:31 EDT 2015

Committee Statement

Committee Statement: The added information provides valuable statistical data.
Response Message:

Public Input No. 29-NFPA 921-2014 [Section No. 30.9 [Excluding any Sub-Sections]]

First Revision No. 40-NFPA 921-2015 [New Section after A.9.10.6.4]

A.9.10.7

For more information on surge voltages and damage to cables see Babrauskas, V. (2006), "Mechanisms and Modes for Ignition of Low-voltage, PVC-insulated Electrotechnical Products," *Fire & Materials* 30 , 150-174.

A.9.10.7.1

For more information on the effects of mechanical damage to cables, including hammer mis-hits, see Babrauskas, V. (2014), "Fires Originating in Branch-Circuit NM Cables due to Installation Damage," pp. 17-28 in *ISFI 2014—Proc. Intl. Symp. on Fire Investigation Science & Technology* . Also see "Influence of Damage and Degradation of NM Cables" Underwriters Laboratories January 28, 2013.

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Wed May 27 15:52:48 EDT 2015

Committee Statement

Committee Statement: To provide references for pertinent material proposed for paragraphs 9.10.7 and 9.10.7.1.

Response Message:

Public Input No. 151-NFPA 921-2014 [New Section after A.9.10.6.4]

First Revision No. 53-NFPA 921-2015 [Section No. A.15.1]

A.15.1

For more information, see the U.S. Bureau of Mines, *Fire and Explosion Manual for Aircraft Accident Investigations*, AD-771191, August 1973. and *Investigation of Fire and Explosion Accidents in the Chemical Mining and Fuel-Related Industries* , as well as Smith, "Firefighter's Role in Preserving the Fire Scene."

U.S. Bureau of Mines, *Investigation of Fire and Explosion Accidents in the Chemical Mining and Fuel-Related Industries — A Manual* , Report 680, Kuchta, 1985.

Smith, D. W. "Firefighter's Role and Responsibility in Preserving the Fire Scene and Physical Evidence," *The Times* , NFPA Fire Service Section (3), September 1995, p. 6 .

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Thu May 28 15:24:02 EDT 2015

Committee Statement

Committee Statement: The change updates the citation to the article listed in Annex A. This is a republication of the same article that is currently referenced, but the new citation makes the article more easily accessible.

Response Message:

First Revision No. 61-NFPA 921-2015 [Section No. A.16.3.2]

A.16.3.2

Figure A.16.3.2(a) through Figure A.16.3.2(p) provide sample forms that can be used for data collection.

Figure A.16.3.2(a) Sample Form for Collecting Fire Incident Field Data.

FIRE INCIDENT FIELD NOTES

Agency: ____________________ File No: ____________

TYPE OF OCCUPANCY

Location/ Address						
Property Description	Structure	Residential	Commercial	Vehicle	Wildland	Other
Other Relevant Info						

WEATHER CONDITIONS

Indicate Relevant Weather Information	Visibility	Rel. humidity	GPS	Elevation	Lightning
	Temperature	Wind direction	Wind speed	Precipitation	

OWNER

Name			DOB
d/b/a (if applicable)			
Address			
Telephone	Home	Business	Cellular

OCCUPANT

Name			DOB
d/b/a (if applicable)			
Permanent Address			
Temporary Address			
Telephone	Home	Business	Cellular

DISCOVERED BY

Incident Discovered by	Name		DOB
Address			
Telephone	Home	Business	Cellular

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FIRE INCIDENT FIELD NOTES

Agency: ____________________ File No: ____________

TYPE OF OCCUPANCY

Location/ Address						
Property Description	Structure	Residential	Commercial	Vehicle	Wildland	Other
Other Relevant Info						

WEATHER CONDITIONS

Indicate Relevant Weather Information	Visibility	Rel. humidity	GPS	Elevation	Lightning
	Temperature	Wind direction	Wind speed	Precipitation	

OWNER

Name			DOB
d/b/a (if applicable)			
Address			
Telephone	Home	Business	Cellular

OCCUPANT

Name			DOB
d/b/a (if applicable)			
Permanent Address			
Temporary Address			
Telephone	Home	Business	Cellular

DISCOVERED BY

Incident Discovered by	Name		DOB
Address			
Telephone	Home	Business	Cellular

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Figure A.16.3.2(b) *Continued*

FIRE INCIDENT FIELD NOTES (Continued)

File No: ______________________

REPORTED BY

Incident Reported by	Name		DOB
Address			
Telephone	Home	Business	Cellular

INVESTIGATION INITIATION

Request Date and Time	Date of request	Time of request
Investigation Requested by	Agency name	Contact person/Telephone no.
Request Received by	Agency name	Contact person/Telephone no.

SCENE INFORMATION

Arrival Information	Date		Time		Comments		
Scene Secured	Yes	No	Securing agency		Manner of security		
Authority to Enter	Contemporaneous to exigency		Consent		Warrant		
			Written	Verbal	Admin.	Crim.	Other
Departure Information	Date		Time		Comments		

OTHER AGENCIES INVOLVED

	Dept. or Agency Name	Incident No.	Contact Person/Phone
Primary Fire Department			
Secondary Fire Department(s)			
Law Enforcement			
Private Investigators			

ADDITIONAL REMARKS

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FIRE INCIDENT FIELD NOTES (Continued)

File No: ______________________

REPORTED BY

Incident Reported by	Name		DOB
Address			
Telephone	Home	Business	Cellular

INVESTIGATION INITIATION

Request Date and Time	Date of request	Time of request
Investigation Requested by	Agency name	Contact person/Telephone no.
Request Received by	Agency name	Contact person/Telephone no.

SCENE INFORMATION

Arrival Information	Date		Time		Comments		
Scene Secured	Yes	No	Securing agency		Manner of security		
Authority to Enter	Contemporaneous to exigency		Consent		Warrant		
			Written	Verbal	Admin.	Crim.	Other
Departure Information	Date		Time		Comments		

OTHER AGENCIES INVOLVED

	Dept. or Agency Name	Incident No.	Contact Person/Phone
Primary Fire Department			
Secondary Fire Department(s)			
Law Enforcement			
Private Investigators			

ADDITIONAL REMARKS

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Figure A.16.3.2(c) Sample Form for Collecting Casualty Field Data.

CASUALTY FIELD NOTES

Agency: ____ Incident date: ____ Case number: ____

DESCRIPTION

Name: ____ DOB: ____ Sex/Race: ____
Address: ____ Phone: ____
Other identifiers: ____
Description of clothing and jewelry: ____
Occupation: ____ Place of employment: ____
Marital status: ____
Victim's doctor: ____ Victim's dentist: ____
Smoker: ❑ Yes ❑ No ❑ Unknown

CASUALTY TREATMENT

Treated at scene: ❑ Yes ❑ No By: ____
Transported to: ____ Remarks: ____

SEVERITY OF INJURY

❑ Minor ❑ Moderate ❑ Severe ❑ Fatal
Describe injury: ____

NEXT OF KIN

Name: ____ Address: ____ Phone: ____
Relationship: ____ Notified on ___/___/___ By: ____

FATALITY INFORMATION

Where was victim initially found: ____
Who located victim: ____
Body position when initially found: ____
Victim's appearance: ____
Body removed by: ____ To: ____
Photographed in place: ❑ Yes ❑ No Significant blood present under/near victim: ❑ Yes ❑ No

MEDICAL EXAMINER/CORONER

Agency: ____
Date of examination: ___/___/___ Location: ____
Autopsy requested: ❑ Yes ❑ No Autopsy completed: ❑ Yes ❑ No Copy attached: ❑ Yes ❑ No
Full body x-rays: ❑ Yes ❑ No Other x-rays: ____
Identification made from: ❑ Physical appearance ❑ Dental records ❑ Fingerprints ❑ Prior injury comparison ❑ Other: ____
Condition of trachea: ____
Evidence of pre-fire injury: ❑ Yes ❑ No Type/location: ____
Blood samples taken: ❑ Yes ❑ No Other specimens collected: ____
CO level: ____ Blood alcohol: ____ Other: ____
Cause of death: ____

COMPLETE BODY DIAGRAM ON REVERSE

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CASUALTY FIELD NOTES

Agency: ____ Incident date: ____ Case number: ____

DESCRIPTION

Name: ____ DOB: ____ Sex/Race: ____
Address: ____ Phone: ____
Other identifiers: ____
Description of clothing and jewelry: ____
Occupation: ____ Place of employment: ____
Marital status: ____
Victim's doctor: ____ Victim's dentist: ____
Smoker: ❑ Yes ❑ No ❑ Unknown

CASUALTY TREATMENT

Treated at scene: ❑ Yes ❑ No By: ____
Transported to: ____ Remarks: ____

SEVERITY OF INJURY

❑ Minor ❑ Moderate ❑ Severe ❑ Fatal
Describe injury: ____

NEXT OF KIN

Name: ____ Address: ____ Phone: ____
Relationship: ____ Notified on ___/___/___ By: ____

FATALITY INFORMATION

Where was victim initially found: ____
Who located victim: ____
Body position when initially found: ____
Victim's appearance: ____
Body removed by: ____ To: ____
Photographed in place: ❑ Yes ❑ No Significant blood present under/near victim: ❑ Yes ❑ No

MEDICAL EXAMINER/CORONER

Agency: ____
Date of examination: ___/___/___ Location: ____
Autopsy requested: ❑ Yes ❑ No Autopsy completed: ❑ Yes ❑ No Copy attached: ❑ Yes ❑ No
Full body x-rays: ❑ Yes ❑ No Other x-rays: ____
Identification made from: ❑ Physical appearance ❑ Dental records ❑ Fingerprints ❑ Prior injury comparison ❑ Other: ____
Condition of trachea: ____
Evidence of pre-fire injury: ❑ Yes ❑ No Type/location: ____
Blood samples taken: ❑ Yes ❑ No Other specimens collected: ____
CO level: ____ Blood alcohol: ____ Other: ____
Cause of death: ____

COMPLETE BODY DIAGRAM ON REVERSE

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Figure A.16.3.2(d) *Continued*

CASUALTY FIELD NOTES (Continued)

REMARKS

BODY DIAGRAM

Indicate parts of body injured: ❑ None ❑ Blisters (red marker) ❑ Burns (black marker)

Top of Head

Fire Investigation Data Sheet/Attachment: ______ Initials: ______
Body Diagram

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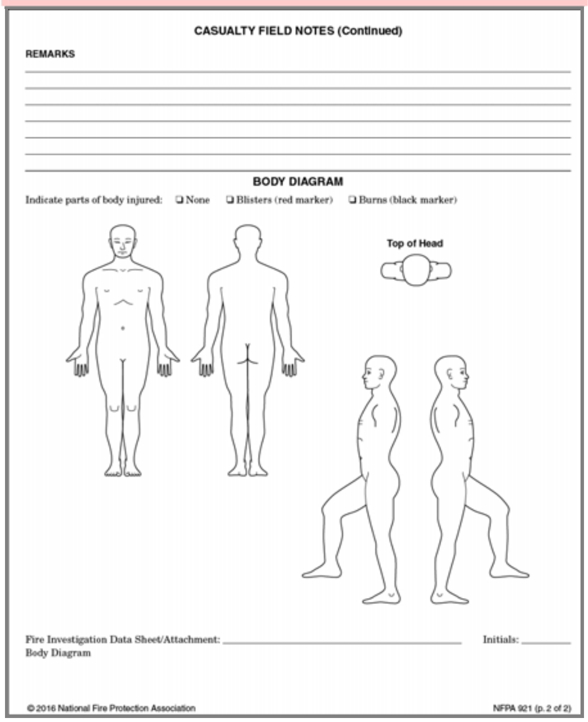

CASUALTY FIELD NOTES (Continued)

REMARKS

BODY DIAGRAM

Indicate parts of body injured: ❑ None ❑ Blisters (red marker) ❑ Burns (black marker)

Top of Head

Fire Investigation Data Sheet/Attachment: ______ Initials: ______
Body Diagram

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Figure A.16.3.2(e) Sample Form for Collecting Wildfire Data.

WILDFIRE NOTES

Agency: ______________ File number: ______________

PROPERTY DESCRIPTION

Fire damage: ❑ Less than acre ______ No. acres	Other properties involved:
Security: ❑ Open ❑ Fenced ❑ Locked gate	Comments:

FIRE SPREAD FACTORS

Type fire: ❑ Ground ❑ Crown	Factors: ❑ Wind ❑ Terrain	Comments:

AREA OF ORIGIN

PEOPLE IN AREA

At time of fire: ❑ Yes ❑ No ❑ Undetermined	Comments:

IGNITION SEQUENCE

Heat of ignition:

Material ignited:

Ignition factor:

If equipment involved: Make: Model: Serial no.:

Comments:

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WILDFIRE NOTES

Agency: ______________ File number: ______________

PROPERTY DESCRIPTION

Fire damage: ❑ Less than acre ______ No. acres	Other properties involved:
Security: ❑ Open ❑ Fenced ❑ Locked gate	Comments:

FIRE SPREAD FACTORS

Type fire: ❑ Ground ❑ Crown	Factors: ❑ Wind ❑ Terrain	Comments:

AREA OF ORIGIN

PEOPLE IN AREA

At time of fire: ❑ Yes ❑ No ❑ Undetermined	Comments:

IGNITION SEQUENCE

Heat of ignition:

Material ignited:

Ignition factor:

If equipment involved: Make: Model: Serial no.:

Comments:

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Figure A.16.3.2(f) Sample Form for Collecting Evidence.

EVIDENCE FORM

Case #: ____________

Date of incident: ___/___/___ Storage location: ____________

Item No.	Description	Location		
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released

How was evidence received? Date received: ___/___/___ Date stored: ___/___/___

❑ Removed from scene by investigator.

❑ Received by investigator from: ____________ Name, Company, or Dept.

Received via: ❑ UPS ❑ FedEx ❑ Airborne ❑ U.S. Mail ❑ In person ❑ Freight ____________ Name of Company

❑ Other: ____________ Describe

____________ Received by ____________ Case Investigator

LOCATION EVIDENCE REMOVED

Owner | State | Zip | Phone

Company | Address 2

Address 1 | City

City | State | Zip | Phone

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EVIDENCE FORM

Case #: ____________

Date of incident: ___/___/___ Storage location: ____________

Item No.	Description	Location		
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released
____	____________	____________	Destroyed	Released

How was evidence received? Date received: ___/___/___ Date stored: ___/___/___

❑ Removed from scene by investigator.

❑ Received by investigator from: ____________ Name, Company, or Dept.

Received via: ❑ UPS ❑ FedEx ❑ Airborne ❑ U.S. Mail ❑ In person ❑ Freight ____________ Name of Company

❑ Other: ____________ Describe

____________ Received by ____________ Case Investigator

LOCATION EVIDENCE REMOVED

Owner | State | Zip | Phone

Company | Address 2

Address 1 | City

City | State | Zip | Phone

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Figure A.16.3.2(g) *Continued*

EVIDENCE FORM (Continued)

INTERNAL EXAMINATION

Investigator	Date Pulled	Date Examined	Date Returned

EVIDENCE DESTRUCTION

Authorized by — Date

Investigator's Authorization — Date

Destroyed by — Date

EVIDENCE RELEASE

Signature of Person Receiving Evidence

Person Receiving Evidence (Please Print) — Date

Company Name

Address

City — State — Zip Code

Authorized by — Date

Investigator's Authorization — Date

Released via

REMARKS

EXAMINATION BY OTHERS

Name — Date of Examination

Company

Address

City — State — Zip — Phone

Authorized by

Investigator's Authorization — Date

Name — Date of Examination

Company

Address

City — State — Zip — Phone

Authorized by

Investigator's Authorization — Date

Name — Date of Examination

Company

Address

City — State — Zip — Phone

Authorized by

Investigator's Authorization — Date

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EVIDENCE FORM (Continued)

INTERNAL EXAMINATION

Investigator	Date Pulled	Date Examined	Date Returned

EVIDENCE DESTRUCTION

Authorized by — Date

Investigator's Authorization — Date

Destroyed by — Date

EVIDENCE RELEASE

Signature of Person Receiving Evidence

Person Receiving Evidence (Please Print) — Date

Company Name

Address

City — State — Zip Code

Authorized by — Date

Investigator's Authorization — Date

Released via

REMARKS

EXAMINATION BY OTHERS

Name — Date of Examination

Company

Address

City — State — Zip — Phone

Authorized by

Investigator's Authorization — Date

Name — Date of Examination

Company

Address

City — State — Zip — Phone

Authorized by

Investigator's Authorization — Date

Name — Date of Examination

Company

Address

City — State — Zip — Phone

Authorized by

Investigator's Authorization — Date

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Figure A.16.3.2(h) Sample Form for Vehicle Inspection. ***(Source: Applied Technical Services, Inc.)***

VEHICLE INSPECTION FIELD NOTES

Job # ____ File # ____ Date of Occurrence ____
Insured ____ Date of Assignment ____
Address (City, State) ____ Date of Receipt ____
Loss Location ____ Date of Inspection ____
Insp Location ____
Stolen? ❑ Yes ❑ No Recovered by ____ Time of Inspection ____
Police Report ____ Fire Report ____
# of Keys ____ Alarm System? ❑ Yes ❑ No Alarm Type ____
Hidden Keys? ❑ Yes ❑ No Location ____

VEHICLE

Make ____ Model ____ Year ____
VIN ____ Odometer ____

EXTERIOR

Tires	Tire Type	Wheel Type	Tire Tread Depth	Lugs	Missing
LF					
LR					
RR					
RF					
SP					

Doors	Glass Y/N	Window UP/DOWN	Locked Y/N	Open/Closed	Prior Damage
LF					
LR					
RR					
RF					

Body Panels	Construction	Condition	Prior Damage
F Bumper			
Grill			
LF Fender			
LR Quarter			
R Bumper			
RR Quarter			
RF Fender			
Hood			
Roof			
Trunk			

UNDER HOOD	Intact	Missing	Parts Missing	Condition
Engine				
Battery				
Belts & Hoses				
Wiring				
Accessories				

FLUIDS	Level	Condition	Sample Taken
Oil			
Transmission			
Radiator			
Pwr Steer			
Brake			
Clutch			

ATS 851B, 8/97 NFPA 921 (p. 1 of 2)

Figure A.16.3.2(i)

INSURANCE INFORMATION

Agency: ____ File number: ____

COMPANY

Name 1.	Address		Phone no.
Policy no.		Effective date	Expiration date
Name 2.	Address		Phone no.
Policy no.		Effective date	Expiration date

COVERAGE

Structure/vehicle	Contents, personal property	Business interruption, loss earnings, living expenses
1. ❑ New ❑ Renewal	Name of insured	Address of insured
2. ❑ New ❑ Renewal	Name of insured	Address of insured
Previous insurance carrier name	Address	Phone no.

$ ____ Structure/vehicle $ ____ Contents $ ____ Other ? ____
Previous losses, cancellations

INSURANCE AGENT

Name 1.	Address	Phone no.
Name 2.	Address	Phone no.

ADJUSTER/INVESTIGATOR

Name of company adjuster/investigator 1.	Address	Phone no.
Name of company adjuster/investigator 2.	Address	Phone no.
Name of public adjuster	Address	Phone no.

TOTAL PAID LOSS

Structure 1. $	Contents/personal property 1. $	Other (Explain) 1. $
Structure 2. $	Contents/personal property 2. $	Other (Explain) 2. $

REMARKS

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Figure A.16.3.2(j)

RECORDS/DOCUMENTS

Agency: ________________ File number: ________________

Use this form as a checklist to indicate which records have been considered in the investigation. The Remarks sections should be used to note availability, contacts, and so forth.

INCIDENT RELATED

Fire dept. name	Incident no.	Remarks
Police dept. name	File no.	Remarks
Insurance co. name	Case no.	Remarks
Gas co. name	Remarks	
Electric co. name	Remarks	
Media coverage	Remarks	
Media coverage	Remarks	
Media coverage	Remarks	
Other–incident related	Remarks	
Other–incident related	Remarks	

PROPERTY RECORDS

Mortgage holder	Remarks
Lien holder	Remarks
Tax records	Remarks
Contracts/leases	Remarks
Titles/registrations	Remarks
Zoning/codes	Remarks
Deeds	Remarks
Other	Remarks
Other	Remarks

BUSINESS/PERSONAL

Accounting	Remarks
Inventory	Remarks
Banks/credit unions, etc.	Remarks
Business and personal tax	Remarks
Criminal history	Remarks
Civil litigations	Remarks

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Figure A.16.3.2(k) ***Continued***

VEHICLE INSPECTION FIELD NOTES (Continued)

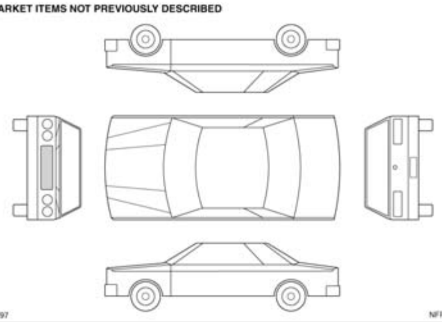
Job # ________________

INTERIOR	Intact	Missing	Parts Missing	Condition
Dash Pod				
Glove Box				
Strg Column				
Ignition				
Front Seat				
Rear Seat				
Rear Deck				
			Make/Model	
Stereo				
Speakers				
Accessories				
FLOOR			**Sample Taken**	
LF				
LR				
RR				
RL				

PERSONAL EFFECTS IN THE INTERIOR

TRUNK OR CARGO AREA

AFTERMARKET ITEMS NOT PREVIOUSLY DESCRIBED



ATS 851B, 8/97 NFPA 921 (p. 2 of 2)

Figure A.16.3.2(l) Sample Form for Photograph Log.

PHOTOGRAPH LOG

Roll #: ______ Exposures: ______

Case #: Date:

Camera make/type: Film type: Film speed: ASA:

Number	Description	Location
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
9)		
10)		
11)		
12)		
13)		
14)		
15)		
16)		
17)		
18)		
19)		
20)		
21)		
22)		
23)		
24)		
25)		
26)		
27)		
28)		
29)		
30)		
31)		
32)		
33)		
34)		
35)		
36)		

Photos taken by: ______ Initials: ______

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PHOTOGRAPH LOG

Roll #: ______ Exposures: ______

Case #: Date:

Camera make/type: Film type: Film speed: ASA:

Number	Description	Location
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
9)		
10)		
11)		
12)		
13)		
14)		
15)		
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Photos taken by: ______ Initials: ______

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Figure A.16.3.2(m) Sample Form for Electrical Panel Data.

ELECTRICAL PANEL DOCUMENTATION

Fire location:	Date:	Case #:
Panel location:	Main size:	Fuses: ☐ Circuit breakers: ☐

LEFT BANK				RIGHT BANK			
#	Rating Amps	Labeled Circuit	Status	#	Rating Amps	Labeled Circuit	Status
1	—		—	2	—		—
3	—		—	4	—		—
5	—		—	6	—		—
7	—		—	8	—		—
9	—		—	10	—		—
11	—		—	12	—		—
13	—		—	14	—		—
15	—		—	16	—		—
17	—		—	18	—		—
19	—		—	20	—		—
21	—		—	22	—		—
23	—		—	24	—		—
25	—		—	26	—		—
27	—		—	28	—		—
29	—		—	30	—		—

Notes: Notes:

Documented by: ____________________

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ELECTRICAL PANEL DOCUMENTATION

Fire location:	Date:	Case #:
Panel location:	Main size:	Fuses: ☐ Circuit breakers: ☐

LEFT BANK				RIGHT BANK			
#	Rating Amps	Labeled Circuit	Status	#	Rating Amps	Labeled Circuit	Status
1	—		—	2	—		—
3	—		—	4	—		—
5	—		—	6	—		—
7	—		—	8	—		—
9	—		—	10	—		—
11	—		—	12	—		—
13	—		—	14	—		—
15	—		—	16	—		—
17	—		—	18	—		—
19	—		—	20	—		—
21	—		—	22	—		—
23	—		—	24	—		—
25	—		—	26	—		—
27	—		—	28	—		—
29	—		—	30	—		—

Notes: Notes:

Documented by: ____________________

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Figure A.16.3.2(n) Sample Form for Structure Fire Data.

STRUCTURE FIRE

Agency: ______________________ Case number: ______________

TYPE OF OCCUPANCY

Residential	Single family	Multifamily	Commercial	Governmental
Church	School	Other:		
Estimated age:	Height (stories):	Length:	Width:	

PROPERTY STATUS

Occupied at time of fire? ❑ Yes ❑ No	Unoccupied at time of fire? ❑ Yes ❑ No	Vacant at time of fire? ❑ Yes ❑ No
Name of person last in structure prior to fire:	Time and date in structure:	Exited via which door/egress:
Remarks:		

BUILDING CONSTRUCTION

Foundation Type	Basement		Crawl space		Slab		Other:
Material	Masonry		Concrete		Stone		Other:
Exterior Covering	Wood	Brick/Stone	Vinyl	Asphalt	Metal	Concrete	Other:
Roof	Asphalt	Wood	Tile		Metal		Other:
Type of Construction	Wood frame	Balloon	Heavy timber	Ordinary	Fire resistive	Non-combustible	Other:

ALARM/PROTECTION/SECURITY

Sprinklers ❑ Yes ❑ No	Standpipes ❑ Yes ❑ No	Security camera(s) ❑ Yes ❑ No
Smoke detectors ❑ Yes ❑ No	Hardwired ❑ Yes ❑ No	Battery ❑ Yes ❑ No
Were batteries in place? ❑ Yes ❑ No	Location(s):	
Hidden keys ❑ Yes ❑ No where:	Security bars: Windows? ❑ Yes ❑ No Doors? ❑ Yes ❑ No	
Remarks:		

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STRUCTURE FIRE

Agency: ______________________ Case number: ______________

TYPE OF OCCUPANCY

Residential	Single family	Multifamily	Commercial	Governmental
Church	School	Other:		
Estimated age:	Height (stories):	Length:	Width:	

PROPERTY STATUS

Occupied at time of fire? ❑ Yes ❑ No	Unoccupied at time of fire? ❑ Yes ❑ No	Vacant at time of fire? ❑ Yes ❑ No
Name of person last in structure prior to fire:	Time and date in structure:	Exited via which door/egress:
Remarks:		

BUILDING CONSTRUCTION

Foundation Type	Basement		Crawl space		Slab		Other:
Material	Masonry		Concrete		Stone		Other:
Exterior Covering	Wood	Brick/Stone	Vinyl	Asphalt	Metal	Concrete	Other:
Roof	Asphalt	Wood	Tile		Metal		Other:
Type of Construction	Wood frame	Balloon	Heavy timber	Ordinary	Fire resistive	Non-combustible	Other:

ALARM/PROTECTION/SECURITY

Sprinklers ❑ Yes ❑ No	Standpipes ❑ Yes ❑ No	Security camera(s) ❑ Yes ❑ No
Smoke detectors ❑ Yes ❑ No	Hardwired ❑ Yes ❑ No	Battery ❑ Yes ❑ No
Were batteries in place? ❑ Yes ❑ No	Location(s):	
Hidden keys ❑ Yes ❑ No where:	Security bars: Windows? ❑ Yes ❑ No Doors? ❑ Yes ❑ No	
Remarks:		

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Figure A.16.3.2(o) *Continued*

STRUCTURE FIRE (Continued)

CONDITION OF DOORS/WINDOWS

Doors	Locked	Unlocked but closed	Open	
	Forced entry? ❑ Yes ❑ No	Who forced if known?		
Windows	Secure	Unlocked but closed	Open	Broken
	Broken by first responders? ❑ Yes ❑ No	Remarks:		

FIRE DEPARTMENT OBSERVATIONS

Name of first on scene:	Department:
General observations:	
Obstacles to extinguishment?	First-In Report attached? ❑ Yes ❑ No

UTILITIES

Electric	❑ On ❑ Off ❑ None	❑ Overhead ❑ Underground	
	Company:	Contact:	Telephone:
Gas/Fuel	❑ On ❑ Off ❑ None	❑ Natural ❑ LP ❑ Oil	
	Company:	Contact:	Telephone:
Water	Company:	Contact:	Telephone:
Telephone	Company:	Contact:	Telephone:
Other	Company:	Contact:	Telephone:

COMMENTS:

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STRUCTURE FIRE (Continued)

CONDITION OF DOORS/WINDOWS

Doors	Locked	Unlocked but closed	Open	
	Forced entry? ❑ Yes ❑ No	Who forced if known?		
Windows	Secure	Unlocked but closed	Open	Broken
	Broken by first responders? ❑ Yes ❑ No	Remarks:		

FIRE DEPARTMENT OBSERVATIONS

Name of first on scene:	Department:
General observations:	
Obstacles to extinguishment?	First-In Report attached? ❑ Yes ❑ No

UTILITIES

Electric	❑ On ❑ Off ❑ None	❑ Overhead ❑ Underground	
	Company:	Contact:	Telephone:
Gas/Fuel	❑ On ❑ Off ❑ None	❑ Natural ❑ LP ❑ Oil	
	Company:	Contact:	Telephone:
Water	Company:	Contact:	Telephone:
Telephone	Company:	Contact:	Telephone:
Other	Company:	Contact:	Telephone:

COMMENTS:

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Figure A.16.3.2(p) Sample Form for Compartment Fire Modeling Fire Data.

COMPARTMENT FIRE MODELING

Room Number ________ Use ________

Size (use diagrams if possible) Wall/floor/ceiling

Construction

Length ________ ________

Width ________ ________

Height ________ ________

Lining materials that represent over 10% of room lining
(Include thickness, density, and other material characteristics if known.)

Wall Material ________ Percentage of Area Involved ________

Ceiling Material ________

Floor or Floor Covering Material ________

Doors, Windows, and Other Openings [Enter all heights as distance above floor. If door sill is at floor, enter zero (0).]

Openings	To Top	To Sill	Width	Changes During Fire (How?)[1]

[1] For example: "Window broke at 10:33" or "Door was closed until opened by escaping occupant, then left open — Exit Time 10:30."

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COMPARTMENT FIRE MODELING

Room Number ________ Use ________

Size (use diagrams if possible) Wall/floor/ceiling

Construction

Length ________ ________

Width ________ ________

Height ________ ________

Lining materials that represent over 10% of room lining
(Include thickness, density, and other material characteristics if known.)

Wall Material ________ Percentage of Area Involved ________

Ceiling Material ________

Floor or Floor Covering Material ________

Doors, Windows, and Other Openings [Enter all heights as distance above floor. If door sill is at floor, enter zero (0).]

Openings	To Top	To Sill	Width	Changes During Fire (How?)[1]

[1] For example: "Window broke at 10:33" or "Door was closed until opened by escaping occupant, then left open — Exit Time 10:30."

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Figure A.16.3.2(q) ***Continued***

COMPARTMENT FIRE MODELING (Continued)

Heating, Ventilation, and Air Conditioning (HVAC). Include air flows from HVAC systems. Give rates and positions of supply and return or exhaust in this room. Also sizes and types of ducts/diffusers.

Tightness of Walls, Closed Windows, Door Fits, etc. (Unless fit is very loose, classify as tight, average, or loose. If fit is very loose, try to get size, number, and location of cracks, etc.)

Doors

Windows

Inside Walls

Exterior Walls

Fire History (List all significant events involving progress of the fire.)

Time (hard or soft)	Event
e.g., 1:10 a.m.	sofa involved, flames 3 feet high
1:17 a.m.	room flashover
1:19 a.m.	large fire plume into hallway
1:23 a.m.	smoke out of third floor window

Initial Fuel Item(s) Description

Description	Size	Material
e.g., sofa	full	polyurethane, with cotton upholstery

Suspected Igniter (List igniter if known with qualification on confidence.)

Igniter: e.g., cigarette

Confidence: probable

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COMPARTMENT FIRE MODELING (Continued)

Heating, Ventilation, and Air Conditioning (HVAC). Include air flows from HVAC systems. Give rates and positions of supply and return or exhaust in this room. Also sizes and types of ducts/diffusers.

Tightness of Walls, Closed Windows, Door Fits, etc. (Unless fit is very loose, classify as tight, average, or loose. If fit is very loose, try to get size, number, and location of cracks, etc.)

Doors

Windows

Inside Walls

Exterior Walls

Fire History (List all significant events involving progress of the fire.)

Time (hard or soft)	Event
e.g., 1:10 a.m.	sofa involved, flames 3 feet high
1:17 a.m.	room flashover
1:19 a.m.	large fire plume into hallway
1:23 a.m.	smoke out of third floor window

Initial Fuel Item(s) Description

Description	Size	Material
e.g., sofa	full	polyurethane, with cotton upholstery

Suspected Igniter (List igniter if known with qualification on confidence.)

Igniter: e.g., cigarette

Confidence: probable

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Supplemental Information

File Name	Description
Staff_only_FR_61_A.16.3.2_Forms.pdf	1. Two new forms.

Submitter Information Verification

Submitter Full Name: Michael Wixted

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Sat May 30 17:36:22 EDT 2015

Committee Statement

Committee Statement: See FR-54.

Response Message:

First Revision No. 74-NFPA 921-2015 [Section No. A.19.6.5]

A.19.6.5

For more information, see ~~the following:~~ Smith, ~~Dennis W.,~~ "The Pitfalls, Perils and Reasoning Fallacies of Determining the Fire Cause in the Absence of Proof: The Negative Corpus Methodology," ~~ISFI Proceedings 2006, International Symposium on Fire Investigation Science and Technology, National Association of Fire Investigators, Sarasota, FL, 2006, pp. 313-325; and, The National Fire Investigator, Spring 2007, NAFI, p. 4-11.~~ and Smith, "The Death of Negative Corpus."

Submitter Information Verification

Submitter Full Name: Michael Wixted

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Street Address:

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Submittal Date: Sun May 31 10:56:54 EDT 2015

Committee Statement

Committee Statement: This reference material provides specific examples and greater detail regarding the use of the Negative Corpus Methodology.

Response Message:

Public Input No. 213-NFPA 921-2014 [Section No. A.19.6.5]

First Revision No. 125-NFPA 921-2015 [Section No. A.22.1]

A.22.1

For more information, see ~~the following:~~ Kimamoto, H., *Probabilistic Risk Assessment and Management for Engineers and Scientists* .

~~Kimamoto, H., *Probabilistic Risk Assessment and Management for Engineers and Scientists* .~~

For examples of studies that incorporate timelines~~,~~ and data development via full-scale and bench-scale fire testing and fire modeling, see~~:~~ Grosshandler, "Report of the Technical Investigation of The Station Nightclub Fire," and Madrzykowski, "Cook County Administration Building Fire, NIST SP-1021, Heat Release Rate Experiments and FDS Simulations."

~~Grosshandler, W.L., "Report of the Technical Investigation of The Station Nightclub Fire."~~

~~Madrzykowski, D., "Cook County Administration Building Fire, NIST SP-1021, "Heat Release Rate Experiments and FDS Simulations."~~

~~Fire~~ For fire test methods, see the following :

NFPA 253, *Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source*.

NFPA 260 , *Standard Methods of Tests and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture* .

NFPA 261 , *Standard Method of Test for Determining Resistance of Mock-Up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes* .

NFPA 286 , *Standard Methods of Fire Tests for Evaluation Contribution of Wall and Ceiling Interior Finish to Room Fire Growth* .

NFPA 289 , *Standard Method of Fire Test for Individual Fuel Packages* .

ASTM D56, *Standard Test Method for Flash Point by Tag Closed Tester*.

ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup*.

ASTM D93, *Standard Test Method for Flash Point by Pensky-Martens Closed Cup Tester*.

ASTM D1230, *Standard Test Method for Flammability of Apparel Textiles*.

ASTM D1310, *Standard Test Method for Flash Point and Fire Point of Liquids by Tag Open-Cup Apparatus*.

ASTM D1929, *Standard Test Method for Determining Ignition Temperature of Plastics*.

ASTM D2859, *Standard Test Method for Flammability of Finished Textile Floor Covering Materials*.

ASTM D3065, *Standard Test Methods for Flammability of Aerosol Products*.

ASTM D3828, *Standard Test Methods for Flash Point by Small Scale Closed Tester*.

ASTM D4809, *Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)*.

ASTM D5305, *Standard Test Method for Determination of Ethyl Mercaptan in LP-Gas Vapor*.

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*.

ASTM E108, *Standard Test Method for Fire Tests of Roof Coverings*.

ASTM E119, *Standard Methods of Fire Tests of Building Construction and Materials*.

ASTM E603, *Standard Guide for Room Fire Experiments*.

ASTM E648, *Standard Test Method for Critical Radiant Flux of Floor-Covering Systems Using a Radiant Heat Energy Source*.

ASTM E659, *Standard Test Method for Autoignition Temperature of Liquid Chemicals*.

ASTM E681, *Standard Test Method for Concentration Limits of Flammability of Chemicals*.

ASTM E800, *Standard Guide for Measurement of Gases Present or Generated During Fires*.

ASTM E906/E906M, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products*.

ASTM E1226, *Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts*.

~~ASTM E1352, *Standard Test Method for Cigarette Ignition Resistance of Mock-up Upholstered Furniture Assemblies* .~~

~~ASTM E1353, *Standard Test Methods for Cigarette Ignition Resistance of Components of Upholstered Furniture* .~~

ASTM E1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*.

ANSI/UL 263, *Standard for Safety Fire Tests of Building Construction and Materials*.

Submitter Information Verification

Submitter Full Name: Michael Wixted

Organization: National Fire Protection Assoc

Street Address:

City:

State:

Zip:

Submittal Date: Mon Jun 01 09:33:10 EDT 2015

Committee Statement

Committee Statement: The proposed language makes the provided references current.

Response Message:

Public Input No. 168-NFPA 921-2014 [Section No. A.22.1]

First Revision No. 126-NFPA 921-2015 [Section No. A.25.10.8]

A.25.10.8

For more information, see the following:

(1) Copper, "Compartment Fire-Generated Environment and Smoke Filling"

(2) DeRosa, "Hydrogen Cyanide and Smoke Particle Characteristics, During Combustion of Polyurethane Foams and Other Nitrogen-Containing Materials"

(3) Gann, "Smoke Component Yields from Room-scale Fire Tests"

(4) Gottuk, "Generation of Carbon Monoxide in Compartment Fires"

(5) Lattimer, "Carbon Monoxide Levels in Structure Fires: Effects of Wood in the Upper Layer of a Post-Flashover Compartment Fire"

(6) Levin, "Generation of Hydrogen Cyanide from Flexible Polyurethane Foam Decomposed under Different Combustion Conditions"

(7) Penney, D. G., "Carbon Monoxide Toxicity"

(8) Purser, "Fully enclosed design fires for hazard assessment in relation to yields of carbon monoxide and hydrogen cyanide"

(9) Purser, "Toxicity Assessment of Combustion Products"

~~Copper, L.Y., Compartment Fire-Generated Environment and Smoke Filling , Section 3/Chapter 10, In The SFPE Handbook of Fire Protection Engineering, 3rd edition. Edited by P.J. DiNenno et al. Quincy, MA: NFPA, 2002.~~

~~DeRosa, M and C. Litton, "Hydrogen Cyanide and Smoke Particle Characteristics, During Combustion of Polyurethane Foams and Other Nitrogen-Containing Materials" , U.S. Bureau of Mines, 1991.~~

~~Gann, R., J. Averill, E. Johnsson, M. Nyden, and R. Peacock. Smoke Component Yields from Room-scale Fire Tests . National Institute of Standards and Technology, Gaithersburg, MD, 2003.~~

~~Gottuk, D. Generation of Carbon Monoxide in Compartment Fires . Virginia Polytechnic Institute, Blacksburg, VA, 1992.~~

~~Lattimer, B.Y., U. Vandsburger, and R.J. Roby. Carbon Monoxide Levels in Structure Fires: Effects of Wood in the Upper Layer of a Post-Flashover Compartment Fire . Fire Tech. 34, 1998, 325-355.~~

~~Levin, B., M. Paabo, M.L. Fultz, and C. Bailey. Generation of Hydrogen Cyanide from Flexible Polyurethane Foam Decomposed under Different Combustion Conditions . Fire and Materials 9, 1985, 125-134 .~~

~~Purser, D.A., J.A. Rowley, P.J. Fardell, and M. Bensilum. Fully enclosed design fires for hazard assessment in relation to yields of carbon monoxide and hydrogen cyanide. In The Proceedings of the Interflame '99 Conference. Interscience Communications Ltd., London, United Kingdom, 1999, pp. 1163-1169.~~

~~Purser, D.A. "Toxicity Assessment of Combustion Products ," Section 2, Chapter 6, In The SFPE Handbook of Fire Protection Engineering, 3rd edition. Edited by P.J. DiNenno et al. Quincy, MA: NFPA, 2002.~~

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 01 09:41:00 EDT 2015

Committee Statement

Committee Statement: This book would be a useful addition to the list of references.

Response Message:

Public Input No. 296-NFPA 921-2015 [Section No. A.25.10.8]

First Revision No. 127-NFPA 921-2015 [Section No. A.25.10.8.2.2]

A.25.10.8.2.2

The autopsy of a fire victim reports a 70 percent COHb level in the blood. The victim was found in bed, and there is no evidence that the victim moved from that location during the fire. Significant fire damage is present in the bedroom as well as an adjacent room. The level of damage in both rooms is consistent with post-flashover fire conditions. Based on data collected, the Fire Investigator hypothesizes that the fire originated in the adjacent room. It appears that the victim was sleeping and never awakened to the fire before dying. The RMV is estimated to be 8.5 L/min based on common RMV values for resting individuals (see references). Based on a developed timeline, the victim's estimated duration of exposure to carbon monoxide (CO) was 10 minutes. Using the Stewart equation, the concentration of CO required to achieve the victim's COHb level would be approximately 17,500 ppm.

$\%COHb = (3.317 \times 10^{-5})(ppm\ CO)^{1.036}(RMV)(t)$ $70\% = (3.317 \times 10^{-5})(ppm\ CO)^{1.036}(8.5\ L/min)(10\ min)$ $ppm\ CO = (70/\ (3.317 \times 10^{-5} * 8.5\ L/min * 10\ min))^{1/1.036}$ ppm CO ~17,500 ppm **[A.25.10.8.2.2]**

CO concentrations on the order of 17,500 ppm are commonly produced in under-ventilated or post-flashover fires. A well-ventilated fire or smoldering fire would not produce this high level of CO. The toxicological findings further support the Fire Investigators' hypothesis that the fire originated in the adjacent room. Had the fire originated in the victim's room ~~(~~ , assuming that it was not a locally ~~under-ventilated~~ underventilated fire~~)~~ , the victim would have succumbed to thermal injury before accumulating this level of COHb in the victim's blood; the fire would not have produced these high concentrations of CO until it reached post-flashover conditions which are thermally untenable.

In smoldering or nonflaming fires, the rate of CO production is low because of the low mass loss rate of the fuel; such fires generally create CO concentrations of no more than hundreds of parts per million. However, in some cases, where the compartment is small and the smoldering continues for a long time, sufficient CO can be produced to create concentrations on the order of 1,000–1,500 ppm. These levels can cause dizziness and confusion within 20 minutes and death within 1 hour. During the development of a ventilation-controlled flaming fire, but prior to flashover, CO production can lead to concentrations of 10,000 ppm and incapacitation can occur within minutes.

Submitter Information Verification

Submitter Full Name: Michael Wixted
Organization: National Fire Protection Assoc
Street Address:
City:
State:
Zip:
Submittal Date: Mon Jun 01 09:44:50 EDT 2015

Committee Statement

Committee Statement: The committee included some material based on the submission. The language adds further scenarios for a fire investigator based on victims dying from CO poisoning as opposed to burns.

Response Message:

Public Input No. 162-NFPA 921-2014 [Section No. A.25.10.8.2.2]

First Revision No. 153-NFPA 921-2015 [Sections C.1, C.2, C.3]

C.1 Referenced Publications.

The following documents or portions thereof are referenced within the annexes of this guide.

~~Fire Protection Handbook, 20th edition, A. E. Cote, editor, National Fire Protection Association, Quincy, MA, 2008.~~

~~*NFPA 72* , *National Fire Alarm and Signaling Code* , National Fire Protection Association, Quincy, MA , 2010 .~~

~~Bukowski, R., Moore, W., *Fire Alarm Signaling Systems* , third edition, National Fire Protection Association, Quincy, MA, 2003.~~

~~Moore, W., "Fire Alarm Systems", Fire Protection Handbook, 20 th edition, Page 14-3, National Fire Protection Association, Quincy, MA, 2008.~~

~~Olenick, S.N., Roby, R.J., Klassen, M.S., Zhang, W., Sutula, J.A., Worrell, C., Wu, D., D'Souza, V., Ashley, E., DuBois, J., Torero, J.L., & Streit, L.A., "The Role of Smoke Detectors in Forensic Fire Investigation and Reconstruction," presented to the International Symposium on Fire Investigation Science and Technology (ISFI), June 26-28, 2006.~~

~~Bryan, J.L., "Human Behavior in Fire," Fire Protection Handbook, 20 th edition, National Fire Protection Association, Quincy, MA, Section 4, Chapter 1, pg. 4-43, 2008.~~

~~Bryan, J. L., Automatic Sprinkler & Standpipe Systems, 4 th edition, National Fire Protection Association, Quincy, MA, 2006.~~

~~Fire Protection Handbook, 20 th edition, National Fire Protection Association, Quincy, MA, 2008 .~~

~~NFPA 13 , *Standard for the Installation of Sprinkler Systems* , National Fire Protection Association, Quincy, MA , 2013.~~

~~NFPA 750 , *Standard on Water Mist Fire Protection Systems* , National Fire Protection Association, Quincy, MA , 2010 .~~

~~NFPA 13D , *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes* , National Fire Protection Association, Quincy, MA , 2013.~~

~~NFPA 13R , *Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and Including Four Stories in Height* , National Fire Protection Association, Quincy, MA , 2013.~~

~~NFPA 14 , *Standard for the Installation of Standpipe and Hose Systems* , National Fire Protection Association, Quincy, MA , 2013.~~

~~NFPA 15 , *Standard for Water Spray Fixed Systems for Fire Protection* , National Fire Protection Association, Quincy, MA , 2014 .~~

~~NFPA 16 , *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems* , National Fire Protection Association, Quincy, MA , 2011 .~~

~~Custer, R. Meacham, B. and Schifiliti, B., "Design of Detection Systems", *The SFPE Handbook of Fire Protection Engineering,* 4 th edition, Page 4-9, NFPA, Quincy, MA, 2008.~~

~~NFPA 11 , *Standard for Low Expansion Foam,* National Fire Protection Association, Quincy, MA, 2010.~~

~~NFPA 11A , *Standard for Medium and High Expansion Foam Systems,* National Fire Protection Association, Quincy, MA, 2010.~~

~~NFPA 12 , *Standard on Carbon Dioxide Extinguishing Systems,* National Fire Protection Association, Quincy, MA, 2011 .~~

~~NFPA 12A , *Standard on Halon 1301 Fire Extinguishing Systems,* National Fire Protection Association, Quincy, MA, 2009 .~~

~~NFPA 12B , *Standard on Halon 1211 Fire Extinguishing Systems* , National Fire Protection Association, Quincy, MA .~~

~~NFPA 17 , *Standard for Dry Chemical Extinguishing Systems* , National Fire Protection Association, Quincy, MA, 2013.~~

~~NFPA 17A , *Standard for Wet Chemical Extinguishing Systems* , National Fire Protection Association, Quincy, MA, 2013.~~

~~NFPA 2001 , *Standard on Clean Agent Fire Extinguishing Systems,* National Fire Protection Association, Quincy, MA, 2012.~~

~~NFPA 11 , *Standard for Low Expansion Foam,* National Fire Protection Association, Quincy, MA.~~

~~NFPA 11A , *Standard for Medium and High Expansion Foam Systems,* National Fire Protection Association, Quincy, MA.~~

~~NFPA 12 , *Standard on Carbon Dioxide Extinguishing Systems,* National Fire Protection Association, Quincy, MA.~~

~~NFPA 12A , *Standard on Halon 1301 Fire Extinguishing Systems,* National Fire Protection Association, Quincy, MA.~~

~~NFPA 12B , *Standard on Halon 1211 Fire Extinguishing Systems,* National Fire Protection Association, Quincy, MA.~~

~~NFPA 17 , *Standard for Dry Chemical Extinguishing Systems,* National Fire Protection Association, Quincy, MA.~~

~~NFPA 17A , *Standard for Wet Chemical Extinguishing Systems,* National Fire Protection Association, Quincy, MA.~~

~~NFPA 2001 , *Standard on Clean Agent Fire Extinguishing Systems* , National Fire Protection Association, Quincy, MA .~~

~~Custer, R. Meacham, B. and Schifiliti, B., "Design of Detection Systems", *The SFPE Handbook of Fire Protection Engineering,* 4th edition, Page 4-9, NFPA, Quincy, MA, 2008.~~

~~SFPE, Engineering Guide: Guidelines for Substantiating a Fire Model for a Given Application, Society of Fire Protection Engineers, Bethesda, MD, 2011.~~

~~NFPA 170 , *Standard for Fire Safety and Emergency Symbols* , 2006 edition.~~

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C.3 References for Extracts in Informational Sections.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2013 2016 edition

Supplemental Information

File Name	Description
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Committee Statement

Committee Statement: Annex C has been revised to update documents to their current editions, to remove duplicate entries, and to re-organize the Annex to comply with NFPA's editorial style. NFPA's editorial rules require all documents listed in Annex A to be referenced in Annex C. Therefore, reference to documents that are mentioned in Annex A have been added to Annex C and the only other changes to Annex C reflect corresponding changes in Annex A.

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Annex D Photograph Credits

D.1 Image Contributors.

Table D.1 Image Contributors

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6.2.3.2	Joe Sesniak
6.2.5.1	NFPA
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6.2.10.3(c)	Patrick Kennedy
6.2.10.3(d)	Patrick Kennedy
6.2.11(a)	Ryan Cox
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6.2.12.1.1	Joe Sesniak
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6.3.2.5(a)	Hal Lyson
6.3.2.~~3(a)~~ 5(b)	Ryan Cox
6.3.2.~~3(b)~~ 5(c)	Ryan Cox
6.3.2.3(c)	Joe Sesniak
6.3.2.5(a)	Ryan Cox
6.3.2.5(b)	Ron Hopkins
6.3.4.1(a)	U.S. Fire Administration
6.3.4.2(a)	John A. Kennedy & Associates
6.3.4.2(b)	John A. Kennedy & Associates
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6.3.7.2(b)	John Lentini
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6.3.7.8.3(d)	Ryan Cox
6.3.7.8.3(e)	Ryan Cox
6.3.7.8.3(f)	Ryan Cox
6.3.7.8.4(a)	NAFI

Figure	Name
6.3.7.8.4(b)	Ron Hopkins
6.3.7.8.5(a)	Dan Churchward
6.3.7.8.5(b)	Dan Churchward
6.3.7.9(a)	NFPA
6.3.7.9(b)	Christopher L. Mealy, Dan T. Gottuk
6.3.7.10.1	Christopher L. Mealy, Dan T. Gottuk
6.3.7.11.2	Ryan Cox
6.3.7.11.2.2	Patrick Kennedy
6.3.7.12	Dennis Smith
8.3.2.1	Gamewell-FCI
8.3.2.4.1(a)	Kidde
8.3.2.4.1(b)	System Sensor Corp.
8.3.2.4.2	*National Fire Alarm and Signaling Code Handbook*
8.3.2.4.3	*National Fire Alarm and Signaling Code Handbook*
8.3.2.4.4	Xtralis
8.3.2.5.1a	System Sensor Corp.
8.3.2.5.1b	System Sensor Corp.
8.3.2.5.1c	The Protectowire Co., Inc.
8.3.2.5.1d	Kidde-Fenwal
8.3.2.7(a)	Cooper Wheelock, Inc., dba Cooper Notification
8.3.2.7(b)	Cooper Wheelock, Inc., dba Cooper Notification
8.3.2.7(c)	Signal Communications Corp.
8.4.1.2.1	*Fire Protection Handbook*
8.4.1.2.2.1	*Fire Protection Handbook*
8.4.1.2.2.2	*Fire Protection Handbook*
8.4.1.2.2.3	*Fire Protection Handbook*
8.4.1.2.2.4	*Fire Protection Handbook*
8.4.2.4	*Fire Protection Handbook*
8.5.1.3.2	Guardian Services, Inc.
8.5.1.3.3a	*Fire Protection Handbook*
8.5.1.3.3b	*Fire Protection Handbook*
8.5.1.3.4	*Fire Protection Handbook*
8.5.2.5(a)	*Fire Protection Handbook*
8.5.2.5(b)	Tyco Fire Protection Products
8.5.2.6(a)	Fire Protection Handbook
8.5.2.6(b)	Tyco Fire Protection Products
8.5.2.7	Fire Protection Handbook
8.5.2.8	Fire Protection Handbook
9.9.4.5.1	Dan Churchward
~~8.10.4(a)~~ 9.10.4(a)	Dan Churchward
9.10.4(b)	Dan Churchward
9.10.4(c)	Dan Churchward
9.10.4(d)	Dan Churchward
9.10.5	Dan Churchward
9.10.4.1(a)	Matt Benfer
9.10.4.1(b)	Matt Benfer
9.10.4.1(c)	Matt Benfer
9.10.5.1(a)	Joe Sesniak

Figure	Name
9.10.6.4	Chris Bloom
10.9.2.1.1(a)	Patrick Kennedy
10.9.2.1.1(b)	Patrick Kennedy
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10.9.6.1	Patrick Kennedy
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10.9.9.1.1(b)	The U.S. Department of Transportation (DOT) Pipeline Hazardous Material Safety Administration (PHMSA), Office of Pipeline Safety (OPS)
13.1	Patrick Kennedy
13.2.3.5	Ron Hopkins
13.3.1	Patrick Kennedy
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13.3.6	Ron Hopkins
13.4.2	Ron Hopkins
13.6.1	Ron Hopkins
~~16.2.4.2(1)~~ 16.2.5.2(1)	Ryan Cox
~~16.2.4.2(2)~~ 16.2.5.2(2)	Ryan Cox
~~16.2.4.3(3)~~ 16.2.5.2(3)	Ryan Cox
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17.6.2.1	Patrick Kennedy
17.10.1.4(b)	Patrick Kennedy
17.10.1.4(c)	John A. Kennedy & Associates
18.3.2.1	Hal Lyson
18.3.2.7(a)	Hal Lyson
18.3.2.7(b)	Hal Lyson
18.4.3.2(a)	Patrick Kennedy
18.4.3.2(b)	Patrick Kennedy
18.4.4.2(a)	Patrick Kennedy
18.4.4.2(b)	Patrick Kennedy
18.4.5.4	Joe Sesniak
18.4.2	Patrick Kennedy and Jim Shanley
18.4.8.1	
22.4.9	*SFPE Engineering Guide*~~. Guidelines for Sustaining a Fire Model for a given Application. SFPE G.06 2011~~
22.4.9.3(a)	~~Verifying and Validating Current Fire Models for Use in Nuclear Power Plant Applications,~~ NUREG 1824, *Verifications and Validation of Selected Fire Models for Nuclear Power Plants Applications*~~, 2010~~
22.4.9.3(b)	~~Verifying and Validating Current Fire Models for Use in Nuclear Power Plant Applications,~~ NUREG 1824, *Verifications and Validation of Selected Fire Models for Nuclear Power Plants Applications*~~, 2010~~
23.2.2.1	Patrick Kennedy
23.2.2.3	Patrick Kennedy
23.2.3.1.3	Scott Davis
23.3.1	John A. Kennedy & Associates
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Figure	Name
23.3.2(b)	John A. Kennedy & Associates
23.4.1.1	Scott Davis
23.4.1.4(a)	Harris, (1983) , pg. 3
23.4.1.4(b)	Harris, 1983
23.8	GEXCon – *Gas Explosion Handbook*, Figure 4.5
23.8.1	GEXCon – *Gas Explosion Handbook*, Figure 4.5
23.8.2.1.1	GEXCon – *Gas Explosion Handbook*, Figure 4.7
23.8.2.1.7	Van Wingerdan et al., 1991
23.8.2.2.5	Scott Davis
23.9.2(a)	NFPA 68, *Standard on Explosion Protection by Deflagration Venting*
23.9.2(b)	Unpublished data courtesy of U.S. Mine Safety and Health Administration
23.9.3	Adapted from Bartknecht [51]
23.14.4.1.4	Patrick Kennedy
24.2.7.1	Dennis Smith
25.2.5.1	Stoll and Greene, 1959
25.9.3(a)	Rodney Pevytoe
25.9.3(b)	Rodney Pevytoe
25.9.7	Rodney Pevytoe
26.2.2(a)	Jim Finneran
26.2.2(b)	Jim Finneran
26.2.2(c)	Jim Finneran
26.2.3(a)	Jim Finneran
26.2.3(b)	Jim Finneran
26.2.3(c)	Jim Finneran
26.3.2(a)	Michael Knowlton
26.3.2(b)	Michael Knowlton
26.3.2(c)	Michael Knowlton
26.4.4(a)	Jim Finneran
26.4.4(b)	Jim Finneran
26.4.4(c)	Jim Finneran
26.4.4(d)	Jim Finneran
26.4.4(e)	Jim Finneran
26.4.5(a)	Jim Finneran
26.4.5(b)	Jim Finneran
26.5.1.1.2	Joe Sesniak
26.5.1.2.1	Joe Sesniak
26.5.1.3	Joe Sesniak
26.5.2.4.1(a)	Jim Finneran
26.5.2.4.1(b)	Jim Finneran
26.5.3.4.1(c)	Jim Finneran
26.5.2.4.1(d)	Jim Finneran
27.8.1.1(c)	MorrFire Investigations
27.8.1.1(d)	MorrFire Investigations
27.8.1.1(e)	MorrFire Investigations
27.8.1.1(f)	MorrFire Investigations
27.8.1.1(g)	MorrFire Investigations
27.11.1(b)	Robby E. Landis

Figure	Name
27.11.1(c)	Robby E. Landis
27.11.1.2.1(a)	Robby E. Landis
27.11.1.2.1(b)	Robby E. Landis
27.11.1.2.2(a)	Robby E. Landis
27.11.1.2.2(b)	Robby E. Landis
27.11.1.3(a)	Robby E. Landis
27.11.1.3(b)	Robby E. Landis
27.11.1.3(c)	Robby E. Landis
27.11.1.4(a)	Robby E. Landis
27.11.1.4(b)	Robby E. Landis
27.15.2.4.1(a)	T. W. Horton
27.15.4.1(b)	T. W. Horton
27.15.6.8(a)	T.W. Horton
27.15.6.8(b)	T.W. Horton
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28.6.12(b)	Jim Shanley
28.6.13(b)	Jim Shanley
28.6.4.1(c)	Jim Shanley
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30.1(b)	Greg Davis
30.4.3	Greg Davis
30.7.2.1.1.1	Greg Davis
30.7.2.1.1.2	Greg Davis
30.8.3.3	Greg Davis
30.9.2.1	Greg Davis
30.9.2.3(a)	Greg Davis
30.9.2.3(b)	Greg Davis
30.9.3.1	Greg Davis
30.10.1	Greg Davis
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Supplemental Information

File Name	Description
Staff_only_FR_149_Annex_D.docx	1. Revised Annex D.

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State:
Zip:
Submittal Date: Tue Jun 02 12:43:02 EDT 2015

Committee Statement

Committee Annex D has been revised based upon additional images being added, the relocation of sections and

Statement:	the removal of material.
Response Message:	