NFPA®

18A

Standard on Water Additives for Fire Control and Vapor Mitigation

2022

NFPA®

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Standard on Water Additives for Fire Control and Vapor Mitigation

2022 Edition

NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
An International Codes and Standards Organization

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NFPA® 18A

Standard on

Water Additives for Fire Control and Vapor Mitigation

2022 Edition

This edition of NFPA 18A, *Standard on Water Additives for Fire Control and Vapor Mitigation,* was prepared by the Technical Committee on Water Additives for Fire Control and Vapor Mitigation. It was issued by the Standards Council on October 2, 2021, with an effective date of October 22, 2021, and supersedes all previous editions.

This edition of NFPA 18A was approved as an American National Standard on October 22, 2021.

Origin and Development of NFPA 18A

In 1998, the NFPA Standards Council approved the formation of the Technical Committee on Water Additives for Fire Control and Vapor Mitigation. The committee was tasked with having primary responsibility for documents on the manufacture, testing, application, and use of water additives for the control and/or suppression of fire and flammable vapor mitigation, including water additives used to prevent or reduce the spread of fire and the use of water additives in fixed, semi-fixed, mobile, and portable fire suppression systems. The standard they were given was NFPA 18, *Wetting Agents.*

Initially, the committee proposed to combine wetting agents and water additives under one standard. This effort was returned to the committee by Association action in June 2003. As a result, the committee decided to divide this work into two subject areas and standards, retaining and revising NFPA 18 and creating a new standard addressing water additives, NFPA 18A, the first edition of which was issued in 2007.

Changes in the 2011 edition included a reorganization of Chapters 5 and 6, clarification of test procedures and criteria, and the removal of secondary (U.S.) units throughout much of the text.

The 2017 edition underwent extensive technical and editorial revision. Technical changes included a new chapter to address Class C fire test methods to provide the fire service with safe limits for fire attack on energized electrical equipment. Editorial changes included updating the structure of the standard to further comply with the *Manual of Style for NFPA Technical Committee Documents.*

The 2022 edition has been significantly enhanced with the addition of two new chapters. New Chapter 9 provides fire test methods for water additives used for the control and suppression of Class D fires and guidance on fire test procedures for testing, approval, and listing purposes. New Chapter 12 provides the end user with application and design guidelines, tying water additives and their requirements with other NFPA standards. Other changes include a re-write of Chapter 4 to classify hazards with a specific class of fires, updates to Chapter 7 to address the spherical micelle stability test, and editorial changes, including updated references.

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This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

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Committee Scope: This Committee shall have primary responsibility for documents on the manufacture, testing, application, and use of water additives for the control and/or suppression of fire and flammable vapor mitigation including water additives used to prevent or reduce the spread of fire and the use of water additives in fixed, semi-fixed, mobile, and portable fire suppression systems.

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Standard on

Water Additives for Fire Control and Vapor Mitigation

2022 Edition

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced and extracted publications can be found in Chapter 2 and Annex E.

Chapter 1 Administration

1.1 Scope. This standard provides the minimum requirements for water additives used for the control and/or suppression of Class A, Class B, Class C, Class D, Class K, and lithium ion battery fires and the mitigation of flammable vapors.

1.2 Purpose. This standard is intended for the use and guidance of those responsible for purchasing, testing, listing, and using water additives for use on Class A, Class B, Class D, Class K, and lithium ion battery fires and the mitigation of flammable vapors.

1.3* Application. This standard applies to water additives utilized to prevent flammable liquid vapor explosions, remove the flammability of flammable liquid spills, or extinguish Class A, Class B, Class C, Class D, Class K, and lithium ion battery fires.

1.4 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.4.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.4.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.4.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction and only where it is clearly evident that a reasonable degree of safety is provided.

1.5 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.5.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.5.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.6 Units and Formulas. The primary system of measurement for this standard is the International System of Units (SI). Inch-pound units are provided where necessary and applicable.

Chapter 2 Referenced Publications

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

Δ **2.2 NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2022 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2022 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2019 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2022 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2020 edition.

NFPA 1901, *Standard for Automotive Fire Apparatus,* 2016 edition.

2.3 Other Publications.

Δ **2.3.1 ASTM Publications.** ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester,* 2018.

ASTM D97, *Standard Test Method for Pour Point of Petroleum Products,* 2017b.

ASTM D1293, *Standard Test Methods for pH of Water*, 2018.

ASTM D2196, *Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer*, 2020.

ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*, 2015e1.

ASTM D4976, *Standard Specification for Polyethylene Plastics Molding and Extrusion Materials*, 2012.

ASTM E729, *Standard Guide for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians*, 1996, reapproved 2014.

ASTM G1, *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens,* 2003, reapproved 2017e1.

ASTM G31, *Standard Guide for Laboratory Immersion Corrosion Testing of Metals,* 2021.

Δ **2.3.2 EPA Publications.** Environmental Protection Agency, William Jefferson Clinton East Building, 1200 Pennsylvania Avenue, NW, Washington, DC 20460.

EPA Method 537.1, *Determination of Selected Per- and Polyfluorinated Alkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)*, 2018.

OPPTS 835.3110, "Ready Biodegradability," *Fate, Transport, and Transformation Test Guidelines*, January 1998.

OPPTS 850.1075, "Fish Acute Toxicity Test, Freshwater and Marine," *Ecological Effects Test Guidelines,* April 1996 (December 2002).

OPPTS 870.1100, "Acute Oral Toxicity," *Health Effects Test Guidelines*, August 1998.

OPPTS 870.1200, "Acute Dermal Toxicity," *Health Effects Test Guidelines*, June 1996.

OPPTS 870.2400, "Acute Eye Irritation," *Health Effects Test Guidelines*, August 1998.

OPPTS 870.2500, "Acute Dermal Irritation," *Health Effects Test Guidelines*, August 1998.

2.3.3 ISO Publications. International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories,* 2017.

2.3.4 NACE Publications. NACE International, 15835 Park Ten Place, Houston, TX 77084-4906.

NACE TM0169, *Standard Guide for Laboratory Immersion Corrosion Testing of Metals*, 2021.

N **2.3.5 SAE Publications.** SAE International, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

AMS C-9084, *Cloth, Glass, Finished, for Resin Laminates*, 1999.

AMS DTL-23059/5A, *Insulation Sleeving, Electrical, Heat Shrinkable, Polyolefin, Flexible, Crosslinked,* 2018.

AMS S-8802, *Sealing Compound, Fuel Resistant, Integral Fuel Tanks and Fuel Cell Cavities*, 2019.

AMS 3208M, *Chloroprene (CR) Rubber, Weather Resistant, 45-55*, 1998, reaffirmed June 2007.

Δ **2.3.6 UL Publications.** Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 162, *Foam Equipment and Liquid Concentrates*, 1994, revised 2018.

UL 711/ULC CAN-S508, *Rating and Fire Testing of Fire Extinguishers*, 2018.

2.3.7 ULC Publications. Underwriters Laboratories of Canada, 7 Underwriters Road, Toronto, ON M1R 3A9, Canada.

ULC CAN-S560, *Category 3 Aqueous Film-Forming Foam (AFFF) Liquid Concentrates*, 2006, reaffirmed 2016.

Δ **2.3.8 US Government Publications.** US Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Title 40, Code of Federal Regulations, Part 86.113-94, "Air Programs — Fuel Specifications."

Title 40, Code of Federal Regulations, Part 160, "Pesticide Programs — Good Laboratory Practice Standards."

Title 40, Code of Federal Regulations, Part 792, "Toxic Substances Control Act — Good Laboratory Practice."

N **2.3.9 US Military Specifications.** Standardization Documents Order Desk, Building 4D, 700 Robbins Ave., Philadelphia, PA 19111-5094.

MIL-A-A-55859A, *Tube, Nonmetallic, Polyvinyl Chloride (PVC) Flexible (General Use)*, 2002.

MIL-PRF-81733D, *Performance Specification: Sealing and Coating Compound, Corrosion Inhibitive*, 1998.

2.3.10 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2022 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2021 edition.

NFPA 36, *Standard for Solvent Extraction Plants,* 2021 edition.

NFPA 1145, *Guide for the Use of Class A Foams in Fire Fighting,* 2022 edition.

NFPA 1150, *Standard on Foam Chemicals for Fires in Class A Fuels,* 2022 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Standard. An NFPA standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA manuals of style. When used in a generic sense, such as in the phrases "standards development process" or "standards development activities," the term "standards" includes all NFPA standards, including codes, standards, recommended practices, and guides.

3.3 General Definitions.

3.3.1 Application Rate. Amount or volume of water additive solution applied over a specified area, over a specified period of time, typically expressed in liters per minute per square meter (gallons per minute per square foot).

3.3.2 Biodegradability. A measure of the decomposition of organic matter through the action of microorganisms. [**1150,** 2022]

3.3.3 Class A Fires. Class A fires are fires in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics. [**10:**5.2.1]

Δ **3.3.4* Class B Fires.** Class B fires are fires in flammable liquids, combustible liquids, and flammable gases. [**10:**5.2.2]

3.3.5 Class C Fires. Class C fires are fires that involve energized electrical equipment. [**10:**5.2.3]

N **3.3.6 Class D Fires.** Class D fires are fires in combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium. [**10:**5.2.4]

N **3.3.7 Class K Fires.** Class K fires are fires in cooking appliances that involve combustible cooking media (vegetable or animal oils and fats). [**10:**5.2.5]

3.3.8 Combustible Liquid. Any liquid that has a closed-cup flash point at or above 37.8°C.

3.3.9* Concentration. The percent of water additive concentrate contained in a water additive solution.

3.3.10* Demulsification. A process either physical or chemical by which an emulsion is broken down to its original constituents.

3.3.11* Discharge Device. A device designed to discharge water or foam–water solution or water additive solution in a predetermined, fixed, or adjustable pattern.

3.3.12 Eductor (Inductor). A device that uses the Venturi principle to introduce a proportionate quantity of water additive concentrate into a water stream; the pressure at the throat is below atmospheric pressure and will draw in liquid from atmospheric storage.

3.3.13 Emulsification. The process of forming an emulsion. *(See also 3.3.15, Emulsion.)*

3.3.14 Emulsifier. A chemical or mixture of chemicals that along with some energy input promotes the formation of an emulsion.

3.3.15* Emulsion. A heterogeneous system, consisting of at least one immiscible liquid dispersed in another in the form of droplets.

3.3.16* Fixed Monitor (Cannon). A device that delivers a large water additive solution stream and is mounted on a stationary support that either is elevated or is at grade.

3.3.17 Flammable Liquid. A liquid that has a closed-cup flash point that is below 37.8°C and a maximum vapor pressure of 2068 mm Hg at 37.8°C.

3.3.18* Handline. A hose and nozzle that can be held and directed by hand. [**11,** 2021]

3.3.19 Hydrocarbon. A chemical substance consisting of only hydrogen and carbon atoms. [**36,** 2021]

3.3.20 Indirect Attack. Fire-fighting operations involving the application of extinguishing agents to reduce the buildup of heat released from a fire without applying the agent directly onto the burning fuel. [**1145,** 2017]

3.3.21 LC_{50} (Lethal Concentration$_{50}$). The concentration of agent in water, usually expressed as milligrams of agent in a liter or solution, that results in the death of 50 percent of the aquatic test specimens within a specified time frame. [**1150,** 2022]

3.3.22 LD_{50} (Lethal Dosage$_{50}$). The dosage of a chemical, usually expressed as milligrams of the chemical per kilogram of body weight of the test animal, at which 50 percent of the test animals die within a specified time frame. [**1150,** 2022]

3.3.23* Micelle. The basic building unit of an emulsion.

3.3.24 Miscibility. The property of being capable of mixing in any ratio without separation into phases. [**1150,** 2022]

3.3.25 Portable Monitor (Cannon). A device that delivers a large water additive solution stream and is mounted on a movable support or wheels so it can be transported to the fire scene.

3.3.26 Proportioning. The introduction of water additive concentrate at the recommended ratio into the water stream to form a water additive solution.

N **3.3.27 Self-Contained and Semi-Portable Detection, Notification, and Suppression System.** A prepackaged system of listed components capable of detection, notification, and suppression of a fire hazard utilizing water or another listed water additive stored in a tank and delivered by a monitor(s).

3.3.28 Surface Active Agent (Surfactant). A chemical agent that materially reduces the surface tension of water.

3.3.29 Surface Tension. The elastic-like force at the surface of a liquid, which tends to minimize the surface area, causing drops to form. [**1150,** 2022]

3.3.30 Synthetic or Artificial Sea Water. A solution consisting of 1.10 percent magnesium chloride hexahydrate, 0.16 percent calcium chloride dihydrate, 0.40 percent anhydrous sodium sulfate, 2.50 percent sodium chloride, and 95.84 percent deionized or distilled water.

3.3.31 Three-Dimensional (3D) Class B Fire. A liquid fuel fire that flows freely from a vertical height, falling on associated equipment or structure, down to a static pooled surface fire.

3.3.32* Water Additive. An agent that, when added to water in proper quantities, suppresses, cools, mitigates fire and/or vapors, and/or provides insulating properties for fuels exposed to radiant heat or direct flame impingement.

3.3.33* Water Additive Concentrate. The chemical or chemical composition as received from the manufacturer.

3.3.34* Water Additive Solution. A homogeneous mixture of water and water additive concentrate.

Chapter 4 Uses and Limitations

4.1 General. Water additive concentrates used in preventing combustible and flammable liquid vapor explosions, removing the flammability of combustible and flammable liquid spills, or extinguishing fires shall be tested and approved, classified, labeled, or listed by a third-party independent testing/listing organization acceptable to the authority having jurisdiction.

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4.2 Limitations.

Δ **4.2.1** Water additive concentrate shall be mixed only with water.

Δ **4.2.2** Unless otherwise tested, listed, or classified for use on a specific water reactive chemical, water additive solution shall have the same limitations as water with respect to extinguishing fires involving chemicals that react with water to create additional hazards.

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N **4.2.3** Unless otherwise specifically tested, listed, or classified, the use of water additive solution for the extinguishment of fires involving Class B flammable or combustible liquids shall be limited to those fuels not soluble in water.

N **4.2.4** Unless otherwise specifically tested, listed, or classified, the use of fire extinguishers and fixed fire-extinguishing systems using water additive solution shall not be permitted for the extinguishment of fires in commercial cooking equipment that involve combustible cooking media.

N **4.3* Uses and Applications.**

N **4.3.1 Class A Fires.** Water additive solutions for use on the following hazard and applications shall be evaluated for use on Class A fires in accordance with Chapter 6:

(1) Material handling — storage piles, sheds (coal, biomass, grain, gluten, other combustible dust)
(2) Material handling — silos, bunkers, hoppers (coal, biomass, grain, gluten, other combustible dust)
(3) Material handling — dust collectors (coal, biomass, grain, gluten, other combustible dust)
(4) Material handling — conveyors (coal, biomass, grain, gluten, other combustible dust)
(5) Flue gas bag-type dust collectors
(6) Rubber tire and rubber tire recycling (processing, grinding, storage)
(7) Structural firefighting and exposure protection
(8) Other applications as tested, listed, and approved by or acceptable to the authority having jurisdiction

N **4.3.2 Class B 2D Fires.** Water additive solutions for use on the following hazard and applications shall be evaluated for use on Class B 2D fires in accordance with Sections 7.2 or 7.3:

(1) Aircraft (group III hangars, pool fire)
(2) Other applications as tested, listed, and approved by or acceptable to the authority having jurisdiction

N **4.3.3 Class B 3D Fires.** Water additive solutions for use on the following hazard and applications shall be evaluated for use on Class B 3D fires in accordance with Sections 7.4 or 7.5:

(1) Boiler front — multiple oil-fired burners/igniters
(2) Auxiliary boilers
(3) Regenerative air heaters
(4) Transformer — rectifier sets
(5) Transformer — oil-filled
(6) Hydraulic control systems
(7) Turbine — generator area
(8) Turbine — generator bearings
(9) Lubricating oil lines/pressurized oil spray
(10) Lubrication oil reservoirs and handling equipment
(11) Emergency generators
(12) Flammable liquid rack storage
(13) Aircraft (group III hangars)
(14) Other applications as tested, listed, and approved by or acceptable to the authority having jurisdiction

4.3.4* Class C Fires. Water additive solutions for use on the following hazard and applications shall be evaluated for use on Class C fires in accordance with Chapter 8:

(1) Energized electrical cable
(2) Other applications as tested, listed, and approved by or acceptable to the authority having jurisdiction

4.3.5* Class D Fires. Water additive solutions for use on the following hazard and applications shall be evaluated for use on Class D fires in accordance with Chapter 9:

(1) Metals and metal recycling (process, storage)
(2) Transportation, automotive, shipping
(3) Aircraft manufacturing
(4) Other applications as tested, listed, and approved by or acceptable to the authority having jurisdiction

N **4.3.6 Combustible and Flammable Liquid Fuel Spill Control (Nonpolar and Polar).** Water additive solutions for use on the following hazard and applications shall be evaluated for use on

Class B combustible and flammable liquid spill control (nonpolar and polar) in accordance with Section 7.7:

(1)* Combustible and flammable liquid fuel spill
(2) Other applications as tested, listed, and approved by or acceptable to the authority having jurisdiction

N **4.3.7 Combustible and Flammable Liquid Vapor Encapsulation Explosion Prevention (VEEP).** Water additive solutions for use on the following hazard and applications shall be evaluated for Class B combustible and flammable liquid VEEP (nonpolar and polar) in accordance with Section 7.7:

(1) Refinery processing area pipe leaks
(2) Flammable liquid truck loading racks
(3) Pump seal leaks
(4) Distillation column
(5) Other applications as tested, listed, and approved by or acceptable to the authority having jurisdiction

4.4* Compatibility of Water Additive Concentrate and Solutions.

4.4.1 Water additive concentrate of different brands and other types of concentrate intended for fire prevention, control, suppression, extinguishment, or vapor mitigation shall not be mixed.

4.4.2 Premixed solution prepared with water additive concentrate of different brands and premixed solution prepared with other types of concentrate intended for fire prevention, control, suppression, extinguishment, or vapor mitigation shall not be mixed within the same storage container.

4.4.3 Solution generated separately with water additive concentrate of different brands shall be permitted to be applied to a fire in sequence or simultaneously.

4.4.4 Solution generated with water additive concentrate and solution generated with other types of concentrate intended for fire prevention, control, suppression, extinguishment, or vapor mitigation shall be permitted to be applied to a fire in sequence or simultaneously if approved by the authority having jurisdiction.

4.5 Concentrations. Water additive solution shall be used only in concentrations specified by their listing.

Chapter 5 Properties and General Test Protocols for Evaluation of Water Additive Concentrate and Solution

5.1 General.

5.1.1 Water additive concentrate and water additive solution prepared at the concentrations specified for use by the manufacturer shall be subjected to the tests in this chapter.

5.1.2 The tests detailed in this chapter shall be conducted by an approved independent laboratory using laboratory practices in accordance with 40 CFR 160 and 40 CFR 792 and calibration competency in accordance with ISO/IEC 17025, or equivalent as applicable.

5.1.3 The information developed in response to the requirements of this chapter shall be reported on the manufacturer's technical data sheet and made available to potential users.

5.2 Toxicity and Environmental Tests.

5.2.1 Mammalian Toxicity.

Δ **5.2.1.1** Where water additive concentrate and water additive solution prepared at the maximum concentration specified for use by the manufacturer's water additive listing are to be used, they shall be tested in accordance with the following tests or equivalent tests recognized by the authority having jurisdiction:

(1) OPPTS 870.1100, for acute oral toxicity
(2) OPPTS 870.1200, for acute dermal toxicity
(3) OPPTS 870.2400, for acute eye irritation
(4) OPPTS 870.2500, for acute dermal irritation

N **5.2.1.2** Where water additive solution prepared at the maximum concentration specified for use by the manufacturer's water additive listing is to be used, it shall be tested for toxic fluorinated ingredients in accordance with EPA Method 537.1 by an EPA-approved laboratory or a laboratory that is recognized by the authority having jurisdiction.

5.2.1.3* The water additive concentrate and water additive solution prepared at the maximum concentration specified for use by the manufacturer shall not exceed the toxicity limits acceptable to the authority having jurisdiction.

5.2.2 Aquatic Toxicity.

Δ **5.2.2.1** Water additive concentrates and water additive solution prepared at the maximum concentration specified for use by the manufacturer shall be tested, using *Oncorhynchus mykiss* (rainbow trout), in accordance with OPPTS 850.1075, ASTM E729, or an equivalent test procedure that is recognized by the authority having jurisdiction where the water additive is to be used.

5.2.2.2 In accordance with ASTM E729, 10 fish that are 60 days ± 15 days posthatch shall be exposed under static conditions to each level of a water additive solution in soft water as defined in ASTM E729 for 96 hours at 12°C ± 1°C.

5.2.2.3* The water additive concentrate shall have an LC_{50} acceptable to the authority having jurisdiction when tested in accordance with ASTM E729 and when measured after 96 hours of static exposure.

5.2.3 Biodegradability.

5.2.3.1* The concentrate shall be readily biodegradable or biodegradable when tested in accordance with 5.2.3.2 through 5.2.3.5.

Δ **5.2.3.2** The biodegradability of the concentrate shall be determined in accordance with Section M, CO_2 Evolution (Modified Sturm) Test, of OPPTS 835.3110 or equivalent test recognized by the authority having jurisdiction.

5.2.3.3 Testing shall be conducted for a minimum of 28 days and shall be continued until an oxygen depletion plateau is reached.

5.2.3.4 Testing shall be discontinued at the end of 42 days, even if the plateau has not been reached.

5.2.3.5 At least one reference substance shall be used to monitor inoculum activity.

5.3 Physical Properties.

5.3.1 Concentrate Pour Point. The concentrate pour point shall be determined in accordance with ASTM D97.

5.3.2 Concentrate Miscibility.

5.3.2.1 The concentrate shall be miscible in water and result in a homogenous solution at the concentrations specified for use by the manufacturer. Opalescence shall be considered equivalent to homogeneity.

5.3.2.2 The concentrate miscibility shall be determined in accordance with 5.3.2.2.1 through 5.3.2.2.9.

5.3.2.2.1 The water and the concentrate shall be conditioned to each of the temperature combinations shown in Table 5.3.2.2.1.

5.3.2.2.2 Five hundred milliliters of deionized water conditioned to the test temperature shall be added to a 1 L glass beaker.

5.3.2.2.3 A stirrer, as illustrated in Figure 5.3.2.2.3, shall be inserted into the water to the depth shown in the figure.

5.3.2.2.4 The stirrer motor shall be adjusted to 60 rpm ± 10 rpm.

5.3.2.2.5 The required amount of concentrate conditioned to the test temperature shall be added to the beaker of water within 2 seconds.

Table 5.3.2.2.1 Temperature Combinations of Water Additive Concentrates and Water for Miscibility Testing

Water Additive Temperature	Water Temperature
°C	°C
4 ± 1	21 ± 1
21 ± 1	21 ± 1
4 ± 1	4 ± 1
21 ± 1	4 ± 1

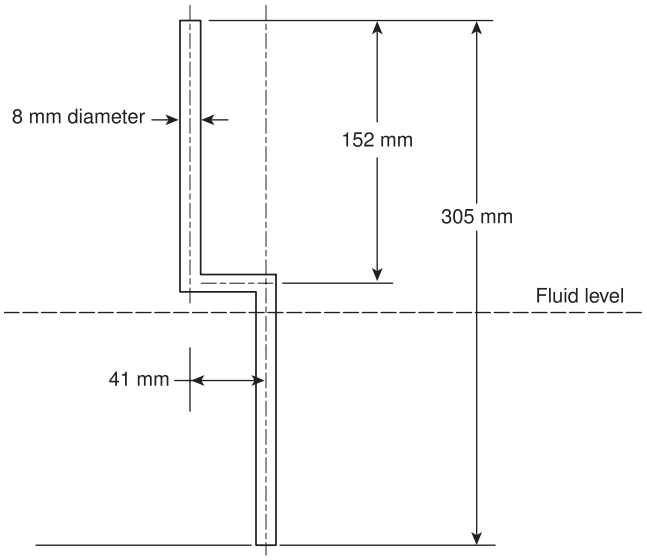

FIGURE 5.3.2.2.3 Stirrer Shaft for Miscibility Test.

5.3.2.2.6 After 10 revolutions of the stirrer, rotation shall be stopped and the liquid shall be visually examined. If the solution is visually homogeneous, the number of revolutions shall be recorded and the result recorded as miscible.

5.3.2.2.7 If the solution is not visually homogeneous, it shall be stirred for an additional 10 revolutions.

5.3.2.2.8 The procedure described in 5.3.2.2.6 and 5.3.2.2.7 shall be repeated until the total number of revolutions is 100 or the solution is visually homogeneous.

5.3.2.2.9 If the solution is not visually homogeneous immediately following 100 revolutions, the results shall be recorded as not miscible.

5.3.3 Concentrate pH. The pH of the concentrate at 18°C ± 2.7°C shall be between 6 and 9 when tested in accordance with ASTM D1293.

5.3.4 Concentrate Viscosity.

5.3.4.1 The concentrate viscosity shall be determined and reported in terms of absolute viscosity (centipoise).

5.3.4.2 Two samples of concentrate shall be conditioned to temperatures of 2°C, 21°C, and 49°C prior to measuring the viscosity.

5.3.4.3* A viscometer rotating at 60 rpm with the appropriate spindle shall be used to measure the viscosity in accordance with ASTM D2196.

5.3.4.4 Triplicate measurements of the viscosity of each sample shall be made, with the sample being stirred gently between measurements.

5.3.4.5 The three viscosity measurements for each sample shall be averaged.

5.3.5 Alternate Viscosity Test Methods.

5.3.5.1 Where the preferred method does not provide usable results, an alternative test method shall be permitted.

5.3.5.2 Where an alternative test method is used, the method and test conditions shall be documented and reported with the reported results.

5.3.6 Concentrate Flash Point. The open cup flash point of the concentrate shall be determined in accordance with ASTM D92.

5.4 Stability.

5.4.1 Concentrate Stability.

5.4.1.1 Three 19 L samples of water additive concentrate from a single production lot shall be stored in sealed containers as described in 5.4.1.4, 5.4.1.5, and 5.4.1.6.

5.4.1.2 The samples shall be designated as Sample 1, Sample 2, and Sample 3.

5.4.1.3* Samples shall not be agitated at any time during or between storage periods.

5.4.1.4 Sample 1.

5.4.1.4.1 Sample 1 shall be stored at 41°C ± 3°C for 30 continuous days.

5.4.1.4.2 At the end of 30 days, Sample 1 shall be removed from the 41°C ± 3°C environment and immediately stored at 21°C ± 2°C for 168 hours.

5.4.1.4.3 Sample 1 shall be handled, opened, and inspected in accordance with 5.4.1.7.

5.4.1.5 Sample 2.

5.4.1.5.1 Sample 2 shall be stored at 41°C ± 3°C for 30 continuous days in a manner identical to that for Sample 1.

5.4.1.5.2 At the end of the 30 days, Sample 2 shall be placed immediately in an environment at a temperature of –10°C ± 1°C.

5.4.1.5.3 Sample 2 shall be kept in this cold environment for a continuous 30-day period.

5.4.1.5.4 At the end of the second 30 days, Sample 2 shall be removed from the –10°C ± 1°C environment and then placed immediately in an environment of 21°C ± 2°C for 168 hours.

5.4.1.5.5 Sample 2 then shall be handled, opened, and inspected in accordance with 5.4.1.7.

5.4.1.6 Sample 3.

5.4.1.6.1 Sample 3 shall be stored at –10°C ± 1°C for 30 continuous days.

5.4.1.6.2 At the end of the 30 days, Sample 3 shall be removed from the –10°C ± 1°C environment and immediately placed at a temperature of 21°C ± 2°C for 168 hours.

5.4.1.6.3 Sample 3 shall then be handled, opened, and inspected in accordance with 5.4.1.7.

5.4.1.7 Concentrate Handling, Opening, and Inspection.

5.4.1.7.1 At the end of the storage periods described in 5.4.1.4 through 5.4.1.6, each sealed sample container shall be inverted four times within a 1-minute period.

5.4.1.7.2 Each sample shall be opened and the water additive concentrate poured into an open pail and allowed to sit undisturbed for 10 minutes to allow bubbles to rise to the surface.

5.4.1.7.3 Each sample then shall be visually examined for separation, stratification, and crystallization.

5.4.1.7.4 Each empty container shall be examined as well for any evidence of residual sediment or crystals.

5.4.1.7.5 The water additive concentrate shall not be stratified, crystallized, or otherwise separated at the end of any test outlined in 5.4.1.

5.4.2 Solution Separation on Standing.

5.4.2.1* If the water additive solution is to be stored for more than 30 days, the water additive solution, in concentrations specified for use by the manufacturer, shall display no tendency to stratify or otherwise separate when stored undisturbed for 30 days in a closed container at the minimum and maximum concentrations and at 21°C ± 3°C.

5.4.2.2 The formation of two or more distinct layers or the presence of precipitate occurring during the course of the test shall be considered as separation.

5.5 Uniform Corrosion.

5.5.1 The water additive and its solutions shall not have corrosion rates exceeding those shown in Table 5.5.1 when tested in accordance with Section 5.5.

Δ Table 5.5.1 Maximum Allowable Corrosion Rates (mils per year) for Wildland Fire Chemical Products

Temperature (°F)	2024-T3 Aluminum				4130 Steel				Yellow Brass	AZ31B Magnesium			
	Total		Partial		Total		Partial		Partial	Total		Partial	
	70	120	70	120	70	120	70	120	120	70	120	70	120
	mils per year												
Concentrates													
Wet concentrates for fixed-tank helicopters	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Wet concentrates[a] except for fixed-tank helicopters	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Mixed products													
Fixed-tank helicopters[b]	2.0	2.0	2.0	2.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0
Fixed-wing air tankers[c]	2.0	2.0	2.0	2.0	5.0	5.0	5.0	5.0	5.0				
Helicopter bucket and ground-based application[a]	2.0	2.0	2.0	2.0	5.0	5.0	5.0	5.0	5.0				

Note: All uniform corrosion rates shall be determined by 90-day weight loss tests. All uniform corrosion rates are the maximum allowable average of all replicates.

[a]Magnesium uniform corrosion tests shall be performed for performance information. Intergranular corrosion tests are not required on aluminum or magnesium.

[b]Intergranular corrosion tests shall be performed on aluminum and magnesium coupons; no intergranular corrosion is allowed.

[c]Intergranular corrosion tests shall be performed on aluminum coupons; no intergranular corrosion is allowed. Magnesium uniform corrosion tests shall be performed for performance information. Intergranular corrosion tests are not required on magnesium.

5.5.2* The concentrate and its solutions at the maximum and minimum use concentrations specified for use by the manufacturer shall be tested to determine the corrosivity to 4130 mild steel, 2024-T3 aluminum, UNS C27000 yellow brass (65 percent copper, 35 percent zinc), and magnesium AZ31B.

Δ **5.5.3** Testing of the corrosive effects of water additive concentrate and its solutions prepared at the minimum and maximum concentrations specified for use by the manufacturer shall be conducted in accordance either with NACE TM0169 or with ASTM G1 and ASTM G31 and in accordance with 5.5.4 through 5.5.9.

5.5.4 Test Coupons.

5.5.4.1* Marking and Measurement. Each coupon, 25 mm × 102.6 mm × 3.2 mm, shall be marked by a vibrating engraver with a unique identification code, drilled in the upper center to insert the braided polyester string used to suspend it, and then measured to the nearest 0.01 mm for length, width, and thickness.

5.5.4.2* A minimum of three test coupons of each alloy shall be exposed to each test liquid (the concentrate and its solutions at the maximum and minimum use concentrations specified for use by the manufacturer) and shall be tested at each of the following test conditions:

(1) Total immersion at 21°C ± 2°C
(2) Total immersion at 49°C ± 2°C
(3) Partial immersion at 21°C ± 2°C
(4) Partial immersion at 49°C ± 2°C

5.5.5 Cleaning and Drying.

5.5.5.1 Degreased coupons shall not be touched with a bare hand, to prevent contamination by skin oils.

5.5.5.2* Each coupon shall be degreased, rinsed in tap water, and then cleaned chemically as described in Table 5.5.5.2, rinsed in deionized water, wiped to remove the water film, and dried at 50°C to 55°C for 15 to 30 minutes.

5.5.5.3 The coupons shall be cooled to room temperature, weighed to 0.1 mg and the weight recorded, and exposed to the test solution.

5.5.6 Test Set-Up.

5.5.6.1 One coupon shall be suspended by a length of braided Dacron fishing line in a 0.95 L glass jar in such a way that the coupon does not touch the sides or the bottom of the jar.

5.5.6.2 Each jar shall contain 0.8 L of liquid for total immersion tests or 0.4 L of liquid for partial immersion tests.

5.5.6.3 For total immersion tests, the coupon shall be completely covered with liquid.

5.5.6.4 For partial immersion tests, the coupon shall be suspended so that 50 percent ± 2.5 mm of its length is exposed to the vapor.

5.5.6.5* Each jar shall be firmly closed with a screw cap, labeled with coupon identification and starting date, and put in an incubator at 21°C or 49°C, depending on the desired test condition.

5.5.7 Test Duration and Completion.

5.5.7.1 Test Duration and Completion. Jars containing the test liquid (three at each exposure and temperature) shall stand undisturbed for 90 days.

5.5.7.2 At the end of the 90-day test period, the coupons shall be removed from the liquid and rinsed under running water to remove loosely attached corrosion products.

5.5.7.3 The coupons shall be lightly scrubbed with a toothbrush or other nonmetallic brush to aid in removal of scale.

5.5.7.4 The coupons shall be cleaned chemically using the same procedures that were used initially in accordance with Table 5.5.5.2.

5.5.7.5 A clean, unused coupon shall be cleaned in the same manner at the same time to serve as a control for weight lost during the cleaning process. The final weight of each coupon shall be determined to 0.1 mg.

Δ **Table 5.5.5.2 Procedures for Cleaning Corrosion Coupons**

Alloy	Cleaning Solution*	Immersion Time (minutes)	Solution Temperature	Remarks
Aluminum	70% HNO_3	2–3	Room temperature	Lightly scrub using nonmetallic brush or scrub pad after immersion. If corrosion film resists cleaning with the HNO_3, alternate with 10-minute immersion in a solution of 2 g CrO_3 and 5 g H_3PO_4 in 93 mL of 80°C to 85°C deionized or distilled water.
Brass	15–20% HCl	2–3	Room temperature	Lightly scrub using nonmetallic brush or scrub pad after immersion. A rubber stopper, Scotch Brite®, or equivalent nonmetallic scourer or scrubber can be used to scrub coupons with hard or severe coating.
Steel	50 g SnCl + 20 g $SbCl_3$ in 1 L conc HCl	3–5	Ice bath	

*Discard cleaning solutions when changing from one product to another and when the cleaning solutions become discolored. Use fresh chemical to clean each magnesium coupon. Exercise care to prevent cross-contamination.
Source: NACE TM0169.

5.5.8 Corrosion Rate.

5.5.8.1 The corrosion rate (*Cr*) in mils per year (mpy) shall be calculated for each sample as follows:

[5.5.8.1]

$$Cr = 534\frac{Wt_i - Wt_f - Wt_c}{Atp}$$

where:
Cr = corrosion rate (mpy)
Wt_i = initial coupon weight (mg)
Wt_f = final coupon weight (mg)
Wt_c = weight loss of the control (mg)
A = area of the coupon (in.^{2})
t = exposure (hours)
p = density of the alloy [g/cm^3 (lb/in.^{3})] as follows: 4130 steel = 7.86 g/cm^3 (0.28 lb/in.^{3}); yellow brass = 8.53 g/cm^3 (0.3 lb/in.^{3}); 2024-T3 aluminum = 2.77 g/cm^3 (0.1 lb/in.^{3})

5.5.9 Results. Results of replicate tests shall be averaged and rounded to the nearest 0.1 mpy.

5.6 Intergranular Corrosion Test.

5.6.1* There shall be no intergranular corrosion on aluminum 2024-T3 when tested in accordance with 5.6.2 through 5.6.5 if the solution is recommended for application by fixed-wing aircraft and magnesium AZ31B for rotary-wing aircraft.

5.6.2 At least one aluminum 2024-T3 coupon for each exposure and temperature condition from the uniform corrosion tests shall be tested for intergranular corrosion.

5.6.3 Each coupon shall be sliced as shown in Figure 5.6.3, mounted, and polished to 0.3 micron alumina finish to make a test specimen.

5.6.4 Polished aluminum test specimens shall be etched with Keller's reagent, and polished magnesium test specimens shall be etched with Nital reagent using standard metallurgical techniques.

5.6.5 The prepared test specimens shall be examined at a magnification of 500× on the transverse and longitudinal cross-sections.

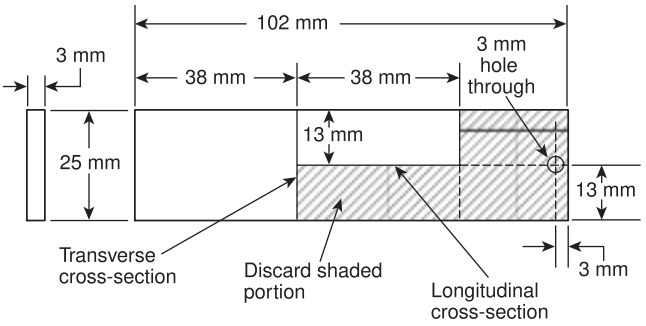

FIGURE 5.6.3 Intergranular Corrosion Test.

5.7 Compatibility with Nonmetallic Materials.

5.7.1 General.

Δ **5.7.1.1** The effect of water additive concentrate and its solutions on the hardness and volume of the following nonmetallic materials shall be determined in accordance with the following:

(1) PVC plastic, type 1 — MIL A-A-55859A
(2) Sealant — SAE AMS S-8802
(3) Sealant — MIL-PRF-81733D
(4) Chloroprene rubber — SAE AMS 3208M
(5) Fiberglass with epoxy resin — SAE AMS C-9084
(6) High-density polyethylene — ASTM D4976
(7) Flexible polyolefin — SAE AMS DTL-23053/5A

5.7.1.2 The degree of change in hardness and volume of the test piece shall be reported in accordance with Section 5.1.

5.7.2 Sample Exposure Tests.

5.7.2.1 Samples of each test material not previously exposed shall be measured to determine volume and hardness as described in 5.7.3 and 5.7.4 before and after exposure to the water additive concentrate and its solutions as described in 5.7.2.2 through 5.7.2.13.

5.7.2.2 The solutions shall be prepared in accordance with the manufacturer's recommendations.

5.7.2.3 A wide-mouth bottle of nominal 125 mL volume, sealable with a nonmetallic screw cap, shall be used as the test container.

5.7.2.4 A sample of the nonmetallic material having a volume of 10 cm^3 to 20 cm^3 shall be prepared with dimensions chosen so that it can be placed in the test container.

5.7.2.5 The sample shall be placed in the container and the container filled with the test concentrate or solution so that the sample is totally immersed.

5.7.2.6 The test container shall be covered loosely and maintained at 21°C during the test.

5.7.2.7 The sample shall be removed from the concentrate or solution without being wiped, rinsed, or dried and placed on top of the container lid for 8 consecutive hours during each 24-hour period for 5 consecutive days.

5.7.2.8 The container shall be closed during atmospheric exposure of the sample.

5.7.2.9 At the end of each atmospheric exposure period, the sample shall be returned to the test container.

5.7.2.10 At the end of five 24-hour test periods, the sample shall remain in the solution for 48 to 63 hours.

5.7.2.11 This cycle shall be repeated until the sample has been subjected to four cycles at the conditions described in 5.7.2.10.

5.7.2.12 Any lost concentrate or solution shall be replenished during the test period so that the sample is totally immersed when in the test solution.

5.7.2.13 At the end of the test period, the sample shall be removed from the liquid, rinsed with distilled water, and air-dried.

5.7.3 Volume Test.

5.7.3.1 The volume of the sample shall be measured to within 1 cm^3 by liquid displacement before and after exposure to the water additive concentrate and its solutions as described in 5.7.2.

5.7.3.2 Volumes shall be recorded.

5.7.3.3 The change in volume shall be calculated and reported as a percentage of the initial volume.

5.7.3.4 The average of triplicate results shall be reported on the manufacturer's product data sheet.

5.7.4 Hardness Test.

5.7.4.1 The hardness of the samples shall be determined following ASTM D2240 prior to and following the procedure described in 5.7.2.

5.7.4.2 A Shore D gauge shall be used for fiberglass and high-density polyethylene.

5.7.4.3 A Shore A2 gauge shall be used for all materials other than fiberglass and high-density polyethylene.

5.7.4.4 The hardness of each sample shall be recorded.

5.7.4.5 The change in hardness shall be calculated and reported on the product data sheet as a percentage of initial hardness.

5.7.4.6 The average of the triplicate results shall be reported.

Chapter 6 Class A Fire Test Methods

6.1* General. Water additive solutions for Class A fuels shall be tested and listed in accordance with all of the following fire test procedures:

(1) Wood panel fire test
(2) Wood crib fire test
(3) Deep-seated fire test

6.2 Wood Panel Fire Test.

Δ **6.2.1** The ability of water additive solutions to extinguish wood panel fires shall be determined with solution prepared at the minimum concentration specified for use by the manufacturer according to the procedures detailed in this section and in UL 711/ULC CAN-S508 for Class A fires utilizing a 3-A wood panel.

6.2.2 The solution shall be applied with a nozzle acceptable to the listing agency at a rate of 19 L/min for 30 seconds, by which time extinguishment shall have been achieved.

6.2.3 Observations shall be continued for 15 minutes following the end of discharge, during which time re-ignition shall not occur.

6.3 Wood Crib Fire Test.

Δ **6.3.1** The ability of water additive solution to extinguish wood crib fires shall be determined with solution prepared at the minimum concentration specified for use by the manufacturer according to the procedures detailed in this section and in UL 711/ULC CAN-S508 for Class A fires utilizing a 3-A wood crib.

6.3.2 The solution shall be applied with a nozzle acceptable to the listing agency at a rate of 19 L/min for 30 seconds, by which time extinguishment shall have been achieved.

6.3.3 Observations shall be continued for 15 minutes following the end of discharge, during which time re-ignition shall not occur.

6.4* Deep-Seated Fire Test. The ability of the water additive solution to extinguish deep-seated fires shall be evaluated for the relevant applications.

Chapter 7 Class B Fire Test Methods

7.1 General. Water additive solutions for Class B fuels shall be tested and listed in accordance with one or more of the following test procedures:

(1) Spill fire test
(2) Pool fire test
(3) Three-dimensional fuel fire test for manual application
(4) Three-dimensional fuel fire test for fixed fire suppression
(5) Polar solvent fire test
(6) Emulsification test
(7) Fuel in depth fire test

7.2* Spill Fire Test.

7.2.1 When tested as described in this section, a water additive prepared at the minimum concentration specified for use by the manufacturer solution shall achieve 100 percent extinguishment in an average of not more than 60 seconds.

7.2.2 The burnback resistance shall be confined to an area of 1.15 m^2 or 25 percent for an average of 180 seconds.

7.2.3 Test Site.

7.2.3.1 The 4.6 m^2 fire test shall be conducted indoors in a level 2.43 m inside diameter pan fabricated from 6 mm thick steel having sides 125 mm high.

7.2.3.2 The pan shall contain 38 L heptane on a substrate of water.

7.2.3.3 The water shall be used only to ensure complete coverage of the pan and shall not exceed 5 mm in depth at the shallowest point of the pan.

7.2.3.4 All fire tests shall be conducted on a surface that is flushed free of fuel and water additive solution from previous tests.

7.2.3.5 The fire test pan shall be cool to the touch before retesting.

7.2.4 Test Equipment.

7.2.4.1 The air-aspirated or non-air-aspirated nozzle or compressed air system, as specified by the manufacturer, shall have a flow rate of 18.9 L/min.

7.2.4.2 When an air-aspirated nozzle or compressed air system is used, foam quality tests shall be conducted and reported in accordance with ULC CAN-S560.

7.2.5 Test Conditions.

7.2.5.1 The temperature of the solution shall be 20°C ± 3°C.

7.2.5.2 The amount of 38 L of commercial grade heptane conforming to UL 162 shall be used.

7.2.5.3 Fuel temperature shall not be less than 10°C.

7.2.5.4 Tests shall be conducted only when the ambient temperature is above 5°C.

7.2.6 Test Procedures.

7.2.6.1 For air-aspirated nozzles and compressed air systems, expansion and drainage testing as described in ULC CAN-S560 shall be conducted prior to initiation of fire testing to confirm equipment functionality.

7.2.6.2 Tests shall be conducted and reported using a solution of water additive liquid concentrate, as received, in freshwater and in synthetic seawater.

7.2.7 Number of Tests.

7.2.7.1 Two sets of two tests, one set with freshwater and one set with synthetic seawater, shall be conducted to derive average extinguishment and burnback times.

7.2.7.2 In the event that either of the averages after the two tests does not meet the requirements of this standard, one more test shall be conducted, with the results of all three tests being averaged.

7.2.7.3 No further testing shall be conducted if either of the averages fails to meet the requirements following the third test.

7.2.8 Test Method.

7.2.8.1 The complete fuel charge shall be emptied into the pan.

7.2.8.2 The fuel shall be ignited within 60 seconds after completion of fueling and shall be permitted to burn freely for 15 seconds before application of the water additive solution.

7.2.8.3 The water additive solution shall be applied for a period of 90 seconds, and the fire shall be extinguished in accordance with the manufacturer's application instructions.

7.2.8.4 The nozzle shall be permitted to be moved throughout the duration of the solution application or fixed in position for part or all of the solution application, but at no time shall the nozzle tip extend beyond the plane of the edge of the pan.

7.2.8.5 The operator shall be permitted to move around the entire area of the pan.

7.2.9* Burnback.

7.2.9.1 A weighted 300 mm diameter pan having 50 mm side walls and charged with 1.1 L of heptane shall be placed in the center of the test area.

7.2.9.2 An eyebolt with a 20 mm shaft attached to the center of the pan and a 3 m pole with a hook on the end shall facilitate the placement of the pan.

7.2.9.3 The fuel shall be ignited, and the burnback pan shall be placed in the 4.6 m^2 fire test pan within 15 seconds after solution application is terminated.

7.2.9.4 Burnback time shall commence at the time of placement of the burnback pan and shall terminate when 25 percent of the fire test pan area is aflame.

7.2.9.5 The burnback pan shall be left in the fire test pan until 25 percent burnback has been achieved.

7.2.10 Data. The following data shall be recorded for each test:

(1) Time for extinguishment (seconds)
(2) Time for 25 percent burnback (seconds)
(3) Ambient temperature
(4) Expansion and drainage (for air-aspirated nozzles or compressed air systems)

7.2.11 Application Rate. The listed application rate shall be 6.89 L/min/m^2.

7.3* Pool Fire Test.

7.3.1 General. Water additive solution prepared at the minimum concentration specified for use by the manufacturer shall be tested in accordance with this section for use on fuels pooled to a depth of 50.8 mm or less.

7.3.1.1 A water additive in combination with an 18.9 L/min nozzle shall be tested in accordance with this section and shall comply with the specified requirements.

7.3.1.2 When an air-aspirated nozzle or compressed air system is used, foam quality tests shall be conducted and reported in accordance with ULC CAN-S560.

7.3.2 Performance. The water additive solution discharged onto flammable liquid test fires shall comply with 7.3.2.1 through 7.3.2.4.

7.3.2.1 The fire shall be completely extinguished during or at the end of discharge.

7.3.2.2 The test fuel surface shall not re-ignite when a lighted torch is moved over all areas of the surface.

7.3.2.3 Candling, flaming, or flashover that self-extinguishes shall be permitted provided that the phenomenon does not remain in one area for more than 30 seconds.

7.3.2.4 When the stovepipe is removed, the liquid surface shall react in either of the following ways:

(1) Restrict the spread of fire at any time during the 3-minute duration to a total area of not more than 0.92 m^2
(2) Flow over and extinguish the burning area

7.3.3 Pretest Storage. Each water additive concentrate to be tested shall be taken from its container as received from the manufacturer, following storage at room temperature for at least 24 hours.

7.3.4 Arrangement of Test.

7.3.4.1 The test fuel of commercial grade heptane conforming to UL 162 shall be placed in a 4.6 m^2 fire test pan constructed in accordance with UL 162.

7.3.4.2 The pan shall be located on the floor.

7.3.4.3 A fuel layer at least 50.8 mm deep shall be added to the pan.

7.3.4.4 The fuel depth shall be adjusted to provide a distance from the top of the pan to the surface of the liquid of not less than 202 mm.

7.3.4.5 Fuel temperature shall not be less than 10°C.

7.3.5 Nozzle Position and Spray Direction.

7.3.5.1 The nozzle shall be positioned in front of and above the test pan.

7.3.5.2 The nozzle shall be permitted to be moved throughout the duration of water additive solution application or fixed in position for part of or all of the application.

7.3.5.3 Until at least 90 percent flame reduction is attained, all water additive solution application shall be from behind one side of the test pan and discharged directly onto the fuel surface.

7.3.5.4 After at least 90 percent flame reduction is attained, water additive solution application shall be permitted to be from the front and one adjacent side and shall be permitted to be directed onto the inside of the test pan.

7.3.5.5 The nozzle shall be permitted to be moved beyond the adjacent side extensions.

7.3.5.6 The nozzle shall not be permitted to extend over any part of the test pan.

7.3.6 Preburn. After the fuel has been added to the test pan and the nozzle has been arranged, the fuel shall be ignited and the resulting fire allowed to burn freely for a 60-second preburn.

7.3.7 Discharge.

7.3.7.1 At the end of the 60-second preburn, the water additive solution shall be discharged for 5 minutes.

7.3.7.2 The fire shall be completely extinguished at or before the end of discharge.

7.3.7.3 After all discharge is complete, the test fuel with water additive solution shall be left undisturbed for 5 minutes.

7.3.8 Re-ignition.

7.3.8.1 During the time the water additive solution with test fuel is left undisturbed, a lighted torch constructed as described in UL 162 shall be passed approximately 25 mm above the entire liquid surface, including corners, in an attempt to re-ignite the fuel.

7.3.8.2 The torch test shall be conducted once during this period and shall commence 2 minutes after the end of agent discharge and prior to the ignition of the 300 mm diameter stovepipe.

7.3.8.3 The torch test shall be conducted for not less than 1 minute.

7.3.8.4 The fuel shall not re-ignite while the torch is being passed over the fuel.

7.3.8.5 Candling, flaming, or flashover that self-extinguishes shall be permitted provided that the phenomenon does not remain in one area for more than 30 seconds.

7.3.9 Burnback.

7.3.9.1 After completion of the attempt to re-ignite the fuel with the lighted torch, a stovepipe constructed as described in UL 162 shall be lowered into the liquid.

7.3.9.2 The stovepipe shall be placed approximately 0.76 m from each of two adjacent sides of the test pan in the corner considered to cause the most severe burnback condition and lowered in such a manner that the liquid surface is not disturbed.

7.3.9.3 The portion of the foam blanket that is enclosed by the stovepipe shall be removed with as little disturbance as possible of the foam blanket outside the stovepipe.

7.3.9.4 If no foam blanket is present, 1 L of heptane shall be poured into the stovepipe.

7.3.9.5 The fuel cleared or placed inside the stovepipe shall be ignited 5 minutes after the end of agent discharge and allowed to burn for 1 minute.

7.3.9.6 The stovepipe then shall be slowly removed from the pan while the fuel continues to burn.

7.3.9.7 When the stovepipe is removed, the liquid surface shall react in either of the following ways:

(1) Restrict the spread of fire at any time during a 3-minute duration to a total area of not more than 0.92 m^2
(2) Flow over and extinguish the burning area

7.3.9.7.1 The spread of fire caused by candling, ghosting, or flashover, in which the flame height exceeds 0.6 m but then self-extinguishes, shall be considered unacceptable if the total area involved in flame exceeds 0.92 m^2 at any time during the 3-minute duration per 7.3.9.7(1).

7.3.10 Application Rate. The listed application rate shall be 10.19 L/min/m^2.

7.4 Three-Dimensional Fuel Fire Test for Manual Application.

7.4.1 General.

7.4.1.1 Water additive concentrates shall be evaluated for aviation applications or industrial applications, or both, and shall be listed only for those applications for which they have been successfully tested.

7.4.1.2 To be listed for the extinguishment of three-dimensional fires, water additive solutions prepared at the minimum concentration specified for use by the manufacturer shall be tested and listed as described in this section. *(See Annex D.)*

7.4.2 Fuel.

7.4.2.1 Water additives shall be tested against a free-flowing running fuel fire.

7.4.2.2 For aviation (*A*) applications, the fuel shall be jet petroleum Grade A.

7.4.2.3 For industrial (*I*) applications, the fuel shall be commercial heptane.

7.4.3* Flow Adjustments. For the purpose of this fire test, fuel shall be adjusted to flow slowly down both sides of the vertical cascade at a total fuel flow rate of 13.25 L/min ± 1.9 L/min.

7.4.4 Wind Speed. Maximum wind speed for this test sequence shall be less than 8 kph.

7.4.5 Water.

7.4.5.1 The lower collection basin of the tower system shall be charged with 101 mm of freshwater at less than 38°C.

7.4.5.2 The vertical tower column shall have water free flowing through the tower cooling system, and the vertical tower temperature prior to the test shall be below 38°C.

7.4.6 Preburn.

7.4.6.1 The basin area shall contain 18.9 L of fuel prior to ignition.

7.4.6.2 The fuel shall be ignited and allowed to preburn for a minimum of 45 seconds.

7.4.6.3 In the event both faces of the test apparatus are not fully involved after 45 seconds, the preburn time shall be extended until full involvement is achieved.

7.4.7 Application of Water Additive.

7.4.7.1 Water additive solution shall be applied with a non-air-aspirated nozzle, an air-aspirated nozzle, or a compressed air–foam system.

7.4.7.2 When an air-aspirated nozzle or compressed air system is used, foam quality tests shall be conducted and reported in accordance with ULC CAN-S560.

7.4.7.3 For aviation fuel, the water additive solution flow rate shall be a maximum of 151 L/min, and extinguishment shall occur in 20 seconds or less.

7.4.7.4 For industrial applications, the water additive solution flow rate shall be a maximum of 227 L/min, and extinguishment shall occur in 45 seconds or less.

7.4.8 Distance to Fire.

7.4.8.1 At the start of application, firefighters shall position themselves at the front of the cascade system at least 6.1 m from the closest corner of the cascade fuel basin.

7.4.8.2 At no time shall a firefighter get closer than 3 m to accomplish the extinguishing process.

7.4.8.3 Firefighters shall remain within an arc of no more than 1.52 m left or right of the closest corner starting point of the collection basin.

7.4.9 Performance. For each application (aviation or industrial) to be listed, three fires in a maximum of six total trials shall meet the performance requirements of 7.4.7.3 or 7.4.7.4.

7.5* Three-Dimensional Fire Test for Fixed Fire Suppression. The ability of the water additive to extinguish three-dimensional fires in fixed suppression systems shall be evaluated for the intended application.

7.6* Polar Solvents Fire Test. (Reserved)

7.7 Encapsulator — Spherical Micelle Stability Test (Liquid Phase Fuels).

7.7.1* General. This section shall cover test procedures to evaluate the ability of a water additive solution to form and maintain stable spherical micelles capable of encapsulating combustible and flammable liquids (nonpolar and polar), rendering the flammable liquids nonflammable, nonignitable, and nonexplosive and maintaining that encapsulation in the presence of high heat over an extended period of time.

7.7.2 Test Materials.

Δ **7.7.2.1** The following materials shall be provided for the test:

(1)* Steel or aluminum pan, square or round, at least 4.8 mm thick and 200 mm high, with a surface area of 4.6 m^2
(2) Amount of water additive concentrate as shown in Table 7.7.3
(3) Type of fuel selected to be tested from the fuels specified in 7.7.2.2
(4) Amount of fuel as shown in Table 7.7.3
(5) Water supply capable of dispensing through a nozzle the amount of water shown in Table 7.7.3
(6) 20 L/min nozzle
(7) Ignition source consisting of a propane torch producing a minimum 25 mm flame

Δ **7.7.2.2** The following fuels shall be tested:

(1) Nonpolar fuels
  (a) Heptane
  (b) Gasoline as defined in 40 CFR 86.113-94
  (c) Gasoline with 10 percent ethanol
  (d) Gasoline with 18 percent methyl tertiary butyl ether (MTBE)
  (e) No. 2 diesel
  (f) Jet A
  (g) Others
(2) Polar fuels
  (a) Alcohol
  (b) Ethanol
  (c) Ethanol blends (E15, E85, other)
  (d) Other

7.7.3* Test Method Procedure. The encapsulator — spherical micelle stability test shall be set up as follows:

(1) The test pan shall be thoroughly washed with clean water and dried.
(2) Using the individual test fuel selected from 7.7.2.2, the full amount of fuel shown in Table 7.7.3 shall be poured into the pan.
(3) The full amount of water additive concentrate shown in Table 7.7.3 shall be mixed into the fuel within 1 minute.
(4) Within 1 minute of adding the fuel and water additive concentrate, the full amount of water shown in Table 7.7.3 shall be added using a 20 L/min nozzle and in a manner to agitate the resulting mixture. Following addition of the water, agitation is to be stopped.
(5) Following the addition of water, agitation shall be stopped.

7.7.4 Ignition Test Procedures.

7.7.4.1 General. Ignition tests for each fuel selected for testing and listing from 7.7.2.2 shall be acceptance tested in accordance with 7.7.4.2 and 7.7.4.3.

7.7.4.2 One-Minute Ignition Test.

7.7.4.2.1 One minute after completion of agitation, the ignition torch described in 7.7.2.1(7) shall be passed over the entire liquid surface, including corners, with the tip of the flame impinging on the surface, in an attempt to re-ignite the fuel.

7.7.4.2.2 The fuel shall not partially or fully ignite while the torch is being passed over the fuel.

N **Table 7.7.3 Encapsulator — Spherical Micelle Stability Test**

Item	Mix Ratio (Part)	SI Units
Water additive	1	Manufacturer's recommendation
Fuel (7.7.2.2)	Fuel ratio = Fuel amount/water additive amount	Manufacturer's recommendation
Water	Water ratio = Water amount/ water additive amount	Manufacturer's recommendation
Kinetic energy — Through agitation of water additive and fuel with water hose stream nozzle over a full 1-minute period.		

7.7.4.3 Two-Hour Ignition Test.

7.7.4.3.1 Two hours after completion of agitation, the ignition torch described in 7.7.2.1(7) shall be passed over the entire liquid surface, including corners, with the tip of the flame impinging on the surface, in an attempt to re-ignite the fuel.

7.7.4.3.2 The fuel shall not partially or fully ignite while the torch is being passed over the fuel.

7.7.5* Acceptance and Listing. When the requirements of 7.7.4.2 and 7.7.4.3 have been successfully met for the selected and tested fuel from 7.7.2.2, the water additive concentrate shall be considered an acceptable encapsulator for the specific fuel tested.

7.8* Fuel in Depth Fire Test. (Reserved)

Chapter 8 Class C Fire Test Methods

8.1 General. Water additive solutions for Class C fires shall be tested and listed in accordance with one or more of the following test procedures:

(1) Extinguisher test
(2) Manual operations test
(3) Arcing conductor test

8.2 Extinguisher Test.

8.2.1 The safe use of water additives in extinguishers to mitigate or suppress a Class C fire shall be evaluated in accordance with Section 8.2.

8.2.1.1* The test and setup shall require a test voltage of 100 kV ac.

8.2.1.2* The extinguisher shall be discharged on the target for a duration of 15 seconds at a minimum distance of 0.92 m (36 in.) from the nozzle to the surface.

8.2.1.3* At no time shall current leakage back to the extinguisher exceed 250 μA.

8.2.2 Water additives shall be evaluated to determine whether the agent pooling will be large enough to expand beyond the standoff distance, which could pose the risk of electrocution.

8.2.3 The entire contents of a maximum 9.5 L (2½ gal) extinguisher shall be discharged onto a vertical surface from a distance of 0.92 m (36 in.).

8.2.3.1 A minimum of half the contents of the extinguisher shall adhere to that vertical surface.

8.2.3.2 The runoff shall not traverse the 0.92 m (36 in.) standoff distance to the discharge point.

8.2.3.3 Agents which spread beyond the standoff distance specified in 8.2.3 shall be required to pass the conductivity test as required by NFPA 10.

8.2.4 The water additive solution shall be tested at both the minimum and maximum concentrations, as specified by the manufacturer's listing.

8.2.5* Use of these extinguishers shall be limited to trained firefighters.

8.3* Manual Operations Test.

8.3.1 The ability of water additives to mitigate or suppress a Class C fire in manual operations shall be evaluated in accordance with Section 8.3.

8.3.2 The agent shall be tested with application and mixing hardware specified by the manufacturer in a consolidated stream and at the maximum flow rate.

8.3.3 The test apparatus shall be configured and the agent prepared for application per the agent manufacturer's published instructions.

8.3.4* Tests shall be conducted using a solution of water additive made with the concentrate, as received, in potable water and at the concentration specified by the manufacturer.

8.3.5 Tests shall be conducted indoors and only when the ambient temperature is above 5°C (40°F).

8.3.5.1 If tested outdoors, wind speeds shall be less than 8 km/hour (5 mph).

8.3.6 Testing shall be conducted in accordance with Section 9 of UL 711/ULC CAN-S508 as modified herein.

8.3.6.1 Testing shall be scaled for manual firefighting operations using ac or dc.

8.3.6.2* The 0.3 m × 0.3 m (12 in. × 12 in.) copper target shall be replaced with a disconnect switch of a compatible voltage rating to support the test process as used in an electrical substation for the category voltage.

8.3.6.3* The disconnect switch shall be energized using a power supply that is capable of supplying the desired test voltage while the insulators isolate the bus bar from ground.

8.3.6.4* A #12 AWG copper wire shall be stripped and inserted into a predrilled 4.8 mm (3/16 in.) hole in the side of the nozzle after the hose coupling.

8.3.6.4.1 The wire shall extend 25.4 mm (1 in.) beyond the tip of the nozzle.

8.3.6.4.2 The wire shall be connected to a ground source with two multimeters placed in series in the circuit.

8.3.6.4.3 One multimeter shall be set to capture milliamps and the other microamps.

8.3.6.5* The two multimeters shall be set to read current, one in milliamps and one in microamps.

8.3.6.6 The current measurements shall be recorded during each test, after stabilization of the readings.

8.3.6.7* The discharge appliance shall be fixed in place on a test stand for safety.

8.3.6.7.1* The stand shall be initially positioned with the nozzle at the test standoff distance for the voltage schedule outlined in Table 8.3.6.7.1.

8.3.6.8 The stream shall be directed onto the target to ensure proper contact.

8.3.6.9 The maximum specified flow rate of the equipment shall be used.

8.3.6.10 The nozzle shall be adjusted to produce the most consolidated (solid) stream possible.

8.3.6.11 After the flow has been established and all personnel are at a safe distance, the target shall be energized to the specified ac/dc voltage.

8.3.6.12 The concentrate shall be proportioned into the water stream at the manufacturer's specified concentration.

8.3.6.13 The solution shall be applied to the target for a minimum period of 90 seconds.

8.3.6.14 Tests shall be repeated while incrementally closing the distance to the target until the leakage current has exceeded the 250 µA threshold.

8.3.6.15 Three tests shall be conducted at a given distance to derive the average leakage current.

8.3.6.16 Acceptable performance shall be defined as maximum leakage current less than 250 µA at 75 percent of the test standoff distance outlined in Table 8.3.6.7.1.

8.3.6.17 Tests VI and VII outlined in Table 8.3.6.7.1 shall be completed using a 30-degree or greater fixed fog pattern with acceptable performance defined as follows:

(1) 110 V–138 kV: <250 µA at 15 ft
(2) 139 kV–765 kV: <250 µA at 30 ft

8.3.6.18 Table 8.3.6.7.1 shall be used to assign a Class C rating category to the water additive solution, based on the distance at which the maximum leakage current criterion was met.

8.3.6.19 The following data shall be recorded for each test:

(1) Water additive and solution concentration
(2) Application and proportioning devices makes and models
(3) Ambient temperature and wind conditions
(4) Viscosity and conductivity of the concentrate and solution
(5) Leakage currents measured, including the maximum and average leakage
(6) Water pressure and flow
(7) Breakdown distance for 250 µA leakage current

8.4* Arc Conductor Test.

8.4.1 The ability of water additives in arc conductor tests to suppress artificially generated faults using copper cables shall be evaluated in accordance with Section 8.4.

8.4.2 The tests shall be monitored for heat release and products of combustion.

8.4.3 Test Protocol.

8.4.3.1 The test arrangement shall be configured indoors.

8.4.3.2 New 500 kcmil copper conductor 600 V ethylene alkene/low smoke non-halogen (EAM/LSNH) installed in a precast concrete distribution box type B-3.6 shall be used to produce a phase-to-phase fault creating an arc with a target fault current of 2 kA at a test voltage of 480 V ac.

8.4.3.3* Tests shall be conducted using a solution of water additive made with the concentrate, as received, in potable water and at the concentration specified by the manufacturer.

8.4.3.4 Water additive concentrate viscosity and conductivity shall be measured and reported.

8.4.3.5 Six tests shall be conducted to derive the average arc suppression results.

8.4.3.5.1 Three tests shall be conducted without the water additive and three tests with the solution.

8.4.3.6* The maximum length of 500 kcmil cable shall be 7.6 m (25 ft).

Table 8.3.6.7.1 Rating Table

		Operating Safe Standoff Distance		Test Standoff Distance	
Category	**Voltage**	**m**	**ft**	**m**	**ft**
I	<600 V	0.3	10	2.3 Solid stream	7.5
II	<34 kV	7.6	25	5.7 Solid stream	18.75
III	<138 kV	22.9	75	17.1 Solid stream	56.25
IV	<345 kV	38.1	125	28.6 Solid stream	93.75
V	<500 kV	41.1	135	30.861 Solid stream	101.25
VI	110 V–138 kV	4.6	15	30-degree fog*	
VII	139 kV–500 kV	9.1	30	30-degree fog*	

*See 8.3.6.18.

8.4.3.6.1 The 500 kcmil cable shall be connected to the 480 V source.

8.4.3.6.2 An inductor shall be placed in series between the voltage source at the faulted cable in the test box to control the current.

8.4.3.6.3 From the inner walls of each cable at the terminal ends, 50.8 mm (2 in.) of insulation shall be removed.

8.4.3.6.4 The cables shall be installed at the bottom of the concrete box, with the terminal ends of each cable positioned so that a 25.4 mm (1 in.) air-gap resides between the stripped portions of cable.

8.4.3.7* The approximate dimensions of the interior volume of the concrete box shall be 0.84 m (33 in.) long by 0.61 m (24 in.) wide by 0.61 m (24 in.) deep.

8.4.3.8 One calorimeter shall be installed above the concrete box to measure the incident energy generated by the fault.

8.4.3.9 The fault duration shall be until the fault self-extinguishes or a steady state is reached.

8.4.3.10 The solution shall be discharged into the concrete service box once the cable has been faulted so that the height of the agent reaches 152.4 mm (6 in.) above the burning cable.

8.4.3.11* Combustible gases shall be measured continuously from 2 minutes prior to the inception of the cable fault through 5 minutes after the solution has risen to the prescribed level.

8.4.3.12* The results of the test shall be evaluated using arc suppression as the criterion for success.

8.4.3.13 The following data shall be recorded for each test:

(1) Arc duration
(2)* Current and voltage waveforms
(3) Ambient temperature
(4) Calorimeter data
(5)* Video (high and normal speed)

N Chapter 9 Class D Fire Test Methods

***N* 9.1 General.** Water additive solutions for Class D fires shall be tested and listed in accordance with the test procedures outlined in Section 9.2.

***N* 9.2 Test Setup.**

***N* 9.2.1* Solid-State Class D Metal.** Magnesium shall be used as the representative Class D material for the test.

***N* 9.2.2 Form of Class D Metal.** Shavings shall be used for the test.

***N* 9.2.3 Quantity of Class D Metal.** For each test evolution, 18 kg of magnesium chips and turnings as defined in UL 711/ULC CAN-S508 shall be used.

***N* 9.2.4 Configuration of Class D Metal.** Material shall be evenly distributed within the backstop at a height of not more than 200 mm.

***N* 9.2.5 Test Apparatus.**

***N* 9.2.5.1** A 4.6 m × 4.6 m steel secondary containment pan with a minimum thickness of 12.7 mm shall be equipped with a 300 mm high flood rim to support the collection of water additive solution run-off.

***N* 9.2.5.2** A 2.1 m × 2.1 m steel test bed with a minimum thickness of 6 mm shall be supported within the center of the secondary containment pan and elevated a minimum of 75 mm above the height of the flood rim.

***N* 9.2.5.3** A 300 mm high, 6 mm thick steel backstop shall be welded at an angle of 120 degrees to the center of the test bed 300 mm from the edge.

***N* 9.2.5.4** The test bed shall be sloped away from the backstop at a decline of 25 mm over 2.1 m.

***N* 9.2.5.5 Test Setup Drawing. (Reserved)**

***N* 9.2.6 Placement and Exposures.** Test apparatus shall be placed on level ground with no combustible materials or vegetation within 7.6 m of the test apparatus.

***N* 9.2.7* Water/Agent Containment.** The secondary containment pan shall be designed to hold a maximum quantity of 3200 L.

***N* 9.2.8 Precautionary Line.** A minimum 40 mm diameter hose line capable of reaching at least 7.6 m past the furthest point of the test apparatus shall be charged with water and staffed during the placement of Class D material through the 30-minute posttest observation.

***N* 9.2.9 Method of Ignition.** A propane torch shall be affixed to the end of a 1.8 m long, 20 mm thick pole to keep the technician a safe distance from material.

***N* 9.2.10 Preburn.** The application of suppression agent shall not begin until the entire surface area of the Class D material is involved in fire, but not less than 1 minute.

***N* 9.2.11 Data Acquisition Devices.** All apparatus used for measurement shall be calibrated and equipped with the following devices:

(1) Flow meters
(2) Pressure measurement device
(3) Temperature measuring device

***N* 9.2.12* Outdoor Test.** An outdoor test — the preferred method — shall be acceptable under the following conditions:

(1) Clear conditions with no rain expected
(2) Above 4.5°C with wind < 16 km/h

***N* 9.3 Application.**

***N* 9.3.1 Nozzle Detail Positioning.** Nozzle detail shall not be positioned inside boundaries of the secondary containment pan.

***N* 9.3.2 Water Supply.** Water shall be applied to the test apparatus from a potable water source.

***N* 9.3.3 Nozzle.** A nozzle capable of producing 95 L/min shall be used.

***N* 9.3.4 Proportioning.** Proportioning of agent shall be specified by the manufacturer.

***N* 9.3.5 Duration of Flow.** Extinguishment shall be achieved within 5 minutes after application of the solution.

N 9.3.6 Data Recording.

N 9.3.6.1 Ambient conditions, such as wind, weather, temperature, and humidity, shall be recorded.

N 9.3.6.2 Data shall be recorded throughout the course of the test at a minimum of 1-minute intervals.

N 9.3.6.3 Data monitoring shall begin at a minimum of 2 minutes prior to ignition and will continue through the 15-minute postsuppression observation.

N 9.4 Acceptable Test.

N 9.4.1 Suppression. Active fire shall be suppressed in 5 minutes with no re-ignition over the 15-minute postfire observation window.

N 9.4.2 Ejection of Class D Material. There shall be no ejection of Class D material outside the secondary containment pan during the suppression process.

N 9.4.3 Replication of Test Process. Upon completion of the first successful test, a second successful test shall be conducted to obtain the listing.

N 9.5 Liquid State Class D Metal Test. (Reserved)

Chapter 10 Packaging and Labeling

10.1 Packaging.

10.1.1* Regulations. Packaging of water additive concentrates shall conform to regulations governing ground and air transport of materials.

Δ 10.1.2 Containers. Containers shall comply with the construction requirements of Section 5.2.1 of UL 162, and nonmetallic containers shall comply with the accelerated storage test of Section 22.3 of UL 162.

10.2 Storage.

10.2.1 Storage of concentrate and premixed solutions shall be provided in accordance with the manufacturers' recommendations.

10.2.2 Water additive concentrate shall not be stored at a temperature below 0°C (32°F) or above 49°C (120°F).

Δ 10.3* Labeling. The manufacturer shall provide the following information on a label permanently attached to the concentrate container:

(1) Manufacturer name and address
(2) Product name, lot number, and date of manufacture
(3) Listed uses and application data in the form of a chart that conforms to Figure 10.3. All boxes must contain appropriate information. If the product is not listed, then the label must indicate this.
(4) The manufacturer's recommended proportioning ratios for each listed application
(5) Flow or application rate for each listed application
(6) Recommended minimum and maximum storage temperatures
(7) Emergency and first aid instructions
(8) Volume of concentrate in container
(9) Listing agency mark

Application	Listed Concentration	Listed Flow Rate	Listing Agency
Spill fire			
Pool fire			
Fuel in depth fire			
3D aviation			
3D industrial			
Polar solvent			
Emulsification			

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Δ FIGURE 10.3 Label Example.

Chapter 11 Supply

11.1 System Requirements.

11.1.1* Equipment. Water additive concentrate complying with this standard shall be permitted to be used with standard equipment provided said equipment is primarily designed to utilize water or foam as a medium of fire control and extinguishment.

11.2 Fire Department Supply Requirements.

11.2.1 Tanks. The manufacturer of the water additive concentrate shall specify if premixing is allowed.

11.2.2* Separate Supplies. Where portable tanks are not a part of the apparatus, or where it is desired that the water additive concentrate be carried separately for use either with water from portable tanks or with water from other sources of supply, the amount of concentrate considered necessary shall be carried in a tank connected to proportioning equipment on the apparatus installed in accordance with NFPA 1901.

Δ **11.3* Fixed Systems.** Fixed systems utilizing water additive solution shall be permitted to be installed in accordance with the following standards as appropriate only after an engineering analysis acceptable to the authority having jurisdiction has been conducted:

(1) NFPA 13
(2) NFPA 14
(3) NFPA 15

N **11.4 Self-Contained and Semi-Portable Detection, Notification, and Suppression Systems.** Water additive concentrates complying with this standard shall be permitted to be used in self-contained and semi-portable detection, notification, and suppression systems, provided the system is designed to use the medium for fire control and extinguishment.

N **Chapter 12 Design Guidelines**

N **12.1 General.** This chapter shall provide guidelines for the design and integration of tested and listed water additives into the fire protection plan outlined in Section 4.3.

N **12.2 Class A Fire Applications.**

N **12.2.1** For Class A fire suppression applications, water additives shall be used at the Class A tested and listed proportioning rate as determined by Chapter 6.

N **12.2.2** Water additives used in manual firefighting shall be applied at the tested and listed proportioning rate as determined by Chapter 6.

N **12.2.3** Water additives used in fixed applications shall be used with standard sprinklers, open-head deluge systems, or other specifically tested and approved or listed systems.

N **12.2.4*** Fixed systems shall be designed, installed, and used in accordance with the minimum sprinkler and application densities and minimum application duration time as specified in the hazard's applicable standard unless a reduction in application sprinkler density or duration time is otherwise justified by the water additive's specific testing and listing for the hazard being protected as acceptable to the authority having jurisdiction.

N **12.3 Class B 2D Fire Applications.**

N **12.3.1** For Class B 2D fire suppression applications, water additives shall be used at the Class B 2D tested and listed proportioning rate as determined by Sections 7.2 or 7.3 for the type of Class B 2D fire.

N **12.3.2** Water additives used in manual firefighting shall be applied at the tested and listed proportioning rate as determined by Sections 7.2 or 7.3 for the type of Class B 2D fire.

N **12.3.3** Water additives used in fixed applications shall be used with standard sprinklers, open-head deluge systems, or other specifically tested and approved or listed systems.

N **12.3.4*** Fixed systems shall be designed, installed, and used in accordance with the minimum sprinkler and application densities and minimum application duration time as specified in the hazard's applicable standard unless a reduction in application sprinkler density or duration time is otherwise justified by the water additive's specific testing and listing for the hazard being protected as acceptable to the authority having jurisdiction.

N **12.4 Class B 3D Fire Applications.**

N **12.4.1** For Class B 3D fire suppression applications, water additives shall be used at the Class B 3D tested and listed proportioning rate as determined by Section 7.4 for the type of Class B 3D fire.

N **12.4.2** Water additives used in manual firefighting shall be applied at the tested and listed proportioning rate as determined by Section 7.4 for the type of Class B 3D fire.

N **12.4.3** Water additives used in fixed applications shall be used with standard sprinklers, open-head deluge systems, or other specifically tested and approved or listed systems.

N **12.4.4*** Fixed systems shall be designed, installed, and used in accordance with the minimum sprinkler and application densities and minimum application duration time as specified in the hazard's applicable standard unless a reduction in application sprinkler density or duration time is otherwise justified by the water additive's specific testing and listing for the hazard as acceptable to the authority having jurisdiction.

N **12.5 Class C Fire Applications.**

N **12.5.1** For Class C fire suppression applications, water additives shall be used at the Class C tested and listed proportioning rate as determined by Chapter 8 for the type of Class C fire.

N **12.5.2** Water additives used in manual firefighting shall be applied at the tested and listed proportioning rate as determined by Chapter 8 for the type of Class C fire.

N **12.5.3** Water additives used in fixed applications shall be used with standard sprinklers, open-head deluge systems, or other specifically tested and approved or listed systems.

N **12.5.4*** Fixed systems shall be designed, installed, and used in accordance with the minimum sprinkler and application densities and minimum application duration time as specified in the hazard's applicable standard unless a reduction in application sprinkler density or duration time is otherwise justified by the water additive's specific testing and listing for the hazard as acceptable to the authority having jurisdiction.

N 12.6 Class D Fire Applications.

N 12.6.1 For Class D fire suppression applications, water additives shall be used at the Class D tested and listed proportioning rate as determined by Chapter 9 for the type of Class D fire.

N 12.6.2 Water additives used in manual firefighting shall be applied at the tested and listed proportioning rate as determined by Chapter 9 for the type of Class D fire.

N 12.6.3 Water additives used in fixed applications shall be used with standard sprinklers, open-head deluge systems, or other specifically tested and approved or listed systems.

N 12.6.4* Fixed systems shall be designed, installed, and used in accordance with the minimum sprinkler and application densities and minimum application duration time as specified in the hazard's applicable standard unless a reduction in application sprinkler density or duration time is otherwise justified by the water additive's specific testing and listing for the hazard as acceptable to the authority having jurisdiction.

N 12.7 Combustible and Flammable Liquid Spill Control Applications.

N 12.7.1 For combustible and flammable liquid spill control applications, water additives shall be used at the encapsulator tested and listed proportioning rate as determined by Section 7.7 for the type of fuel spill being encapsulated and neutralized.

N 12.7.2 Water additives used in manual firefighting shall be applied at the tested and listed proportioning rate as determined by Section 7.7 for the type of fuel spill being encapsulated and neutralized.

N 12.7.3 Water additives used in fixed applications shall be used with standard sprinklers, open-head deluge systems, or other specifically tested and approved or listed systems.

N 12.7.4* Fixed systems shall be designed, installed, and used in accordance with the minimum sprinkler and application densities and minimum application duration time as specified in the hazard's applicable standard unless a reduction in application sprinkler density or duration time is otherwise justified by the water additive's specific testing and listing for the hazard as acceptable to the authority having jurisdiction.

N 12.8 Combustible and Flammable Liquid Vapor Encapsulation Explosion Prevention (VEEP) Applications.

N 12.8.1 For combustible and flammable liquid VEEP applications, water additives shall be used at the encapsulator tested and listed proportioning rate as determined by Sections 7.7 and 7.8 for the type of fuel vapor being encapsulated and neutralized.

N 12.8.2 Water additives used in manual firefighting shall be applied at the tested and listed proportioning rate as determined by Sections 7.7 or 7.8 for the type of fuel vapor being encapsulated and neutralized.

N 12.8.3 Water additives used in fixed applications shall be used with standard sprinklers, open-head deluge systems, or other specifically tested and approved or listed systems.

N 12.8.4* Fixed systems shall be designed, installed, and used in accordance with the minimum sprinkler and application densities and minimum application duration time as specified in the hazard's applicable standard unless a reduction in application sprinkler density or duration time is otherwise justified by the water additive's specific testing and listing for the hazard as acceptable to the authority having jurisdiction.

Chapter 13 Inspection, Testing, and Maintenance of Fixed Systems

13.1* Fixed Extinguishing Systems. Fixed extinguishing systems referenced in Section 11.3 shall be inspected, tested, and maintained in accordance with the applicable system requirements of NFPA 25.

13.2 Inspection of Water Additive Concentrate. Annually, samples of water additive concentrate stored in the fixed system shall be sent to the manufacturer or qualified laboratory for quality condition testing.

Annex A Explanatory Material

Annex A is not a part of the requirements 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.1.3 It is not the intent to preclude agents, such as wetting agents that are Class A or Class B foams, that comply with NFPA 11, NFPA 18, or NFPA 1150 from meeting the requirements of this standard. The scope of this document might include products with extinguishing mechanisms that emulsify fuels and render them inert, but it is not the intent of this standard to include long-term retardants and gels.

Δ **A.3.2.1 Approved.** The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment, or materials, the "authority having jurisdiction" may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The "authority having jurisdiction" may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA standards in a broad manner because jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed

unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.4 Class B Fires. The definition of Class B fires includes many substances for which this standard does not currently contain test protocols, for example, fires involving solvents, lacquers, alcohols, and flammable gases.

A.3.3.9 Concentration. The type of water additive used determines the percentage of concentration required. For example, a 3 percent water additive concentrate is mixed in the ratio of 3 parts water additive to 97 parts water. Liquid concentrates are typically proportioned on a volume rate and solid concentrates by weight.

A.3.3.10 Demulsification. The process can proceed very slowly or very quickly, depending on the stability of the emulsion.

A.3.3.11 Discharge Device. Examples include, but are not limited to, sprinklers, spray nozzles, and hose nozzles.

A.3.3.15 Emulsion. Such systems possess a minimal stability, which can be accentuated by such additives as surface active agents, finely divided solids, and so forth.

A.3.3.16 Fixed Monitor (Cannon). The monitor can be fed solution by permanent piping or hose.

A.3.3.18 Handline. The nozzle reaction usually limits the solution flow to about 1135 L/min. [**11,** 2021]

A.3.3.23 Micelle. For purposes of this standard, a micelle consists of a minute droplet of the hydrocarbon fuel surrounded by water and the emulsifying agent.

A.3.3.32 Water Additive. Water additives can materially reduce water's surface tension and increase its penetrating and spreading abilities; they also might provide enhanced cooling, emulsification, and foaming characteristics.

A.3.3.33 Water Additive Concentrate. For the purposes of this document, *water additive concentrate* and *concentrate* are used interchangeably.

A.3.3.34 Water Additive Solution. For the purposes of this document, *water additive solution* and *solution* are used interchangeably.

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N **A.4.3** Lithium-ion battery and lithium-ion battery energy storage system (BESS) fires are unique electrochemical fire hazards that involve multiple fire classes (Class A, Class B, Class C, Class D) within one entity. While BESS are covered by NFPA 855, it should be noted that lithium-ion battery fires as a stand-alone hazard are not currently addressed in any NFPA standard. According to NFPA research reports, copious amounts of plain water are required to extinguish lithium-ion battery fires, and they can still exhibit thermal runaway up to 72 hours after initial extinguishment.

Water additive based on spherical micelle technology (encapsulator agents) conforming to Section 7.7 has been tested extensively by independent third-party testing organizations, including Kiwa, Dekra, Daimler, Dutech, Bosch, Fraunhofer University, and TU Clausthal. This testing has been controlled, scientific, and highly instrumented, documenting fire suppression, control and elimination of thermal runaway, and encapsulation of both flammable electrolyte and other explosive off-gases, rendering them nonexplosive. Encapsulating technology reduces the toxicity of HF gas exposure to humans.

In addition, the copious amounts of water used to suppress lithium-ion battery fires create copious amounts of run-off containing hydrofluoric acid, creating an environmental issue and expensive HAZMAT disposal cost. Compared to water, water additive solution uses a reasonable amount of solution and has been documented to modify the chemistry of the run-off, making it suitable for additional dilution and disposal in a municipal water treatment plant. Testing documentation can be found in the NFPA Research Library and Archives.

A.4.3.4 If water additive solution comes in contact with electrical equipment, the water additive can remain behind after the water has dried off and can constitute a hazard when the equipment is put back in operation.

Δ **A.4.3.5** Fire test requirements for protection of Class D hazards are addressed by UL 711/ULC CAN-S508.

N **A.4.3.6(1)** Some examples of liquid fuel spill locations include, but are not limited to, fuel spillage on roads from auto accidents, tanker rollovers, train derailments, gas stations, refineries, loading facilities, and airport tarmacs. For a combustible and flammable liquid spill, an encapsulator agent meeting Section 7.7 can be applied to encapsulate the fuel inside a stable spherical micelle to remove the flammability of the fuel.

Using the example encapsulator agent mix ratios shown in A.7.7.3, the fuel neutralization application rate would be a ratio of fuel/water with the encapsulator agent solution being applied at the concentrate's proportion rate. Using an example of 20 L of fuel spilled, the ratio of fuel/water = 8/40, which reduces to 1/5. Therefore, 20 L of fuel × 5 = 100 L of a 2.5 percent encapsulator agent solution would be agitated into the 20 L of fuel to encapsulate and neutralize the fuel. An LEL gas detection meter can be used to show total encapsulation and neutralization. As a double check, if 100 L of 2.5 percent encapsulator agent would have applied 2.5 L of encapsulator agent, then 2.5 L of encapsulator agent × 8 (mix ratio of water additive to fuel) equals 20 L.

A.4.4 The mixing of these concentrates can have adverse effects and render solutions or systems ineffective for fire prevention, control, suppression, extinguishment, or vapor mitigation.

A.5.2.1.3 The toxicity limits listed in Table A.5.2.1.3 have been adopted by several jurisdictions. The limits for oral and dermal toxicity are based on US EPA requirements for the signal word "Caution" required on labels and MSDS data sheets. Higher numbers (LD_{50}) are less toxic to the test species.

A.5.2.2.3 The value of 10 mg/L has been adopted by some authorities having jurisdiction as an acceptable level. This value is based on US EPA categories for testing of aquatic organisms and is equivalent to the categories of slightly toxic and practically nontoxic. Higher numbers are less toxic to the environment.

A.5.2.3.1 If the additive is >60 percent biodegraded after 28 days, it is considered readily biodegradable. If the additive is not readily biodegradable but is ≥60 percent biodegraded after 42 days, the additive is considered to be biodegradable. If it is <60 percent biodegraded after 42 days, it is considered not biodegradable by EPA OPPTS Guidelines.

Table A.5.2.1.3 Toxicity Limits for Water Additive Concentrate and Its Solution

Test Specimen	Acute Oral Toxicity	Acute Dermal Toxicity	Primary Eye Irritation		Primary Dermal Irritation
			Unwashed Eyes	Washed Eyes	
Concentrate	LD_{50} > 500 mg/kg	LD_{50} > 2000 mg/kg	Mildly irritating or less	Mildly irritating or less	Primary irritation score <5.0
			If more irritating, recommend protective gear and safe handling procedures		
Solution	LD_{50} > 5000 mg/kg	LD_{50} > 2000 mg/kg	Mildly irritating or less	Mildly irritating or less	Primary irritation score <5.0

A.5.3.4.3 The Brookfield viscometer models LVT or LVF are two examples of viscometers that can be used for this test. If a Brookfield viscometer is used, then a No. 2 spindle should be used for viscosities from 1 to 500 centipoise and a No. 4 spindle for viscosities greater than 500 centipoise.

A.5.3.5.1 One example of a case where an alternative test method might be used is when the viscosity is too low to produce meaningful results.

A.5.4.1.3 It is important that a sample not be disturbed during the course of the test. When it is necessary to move the sample, care should be taken to minimize movements of concentrate within the container. Rapid motions, shaking, and tilting the samples are examples of undesirable actions.

A.5.4.2.1 Examples of applications where this could occur include the use in fire extinguishers, pre-primed sprinkler systems, booster tanks, and suction tanks.

A.5.5.2 Testing on additional alloys can be necessary in order to meet the needs of the end user. In accordance with Chapter 5, water additive solutions should be tested for compatibility with the materials with which they will be used.

A.5.5.4.1 Test coupons meeting the dimensions provided in this standard should be obtained from a reputable source of corrosion testing materials. Care should be taken to minimize the possibility of work hardening of the metal at the edges, since such improper cutting can have a statistically significant effect on the corrosion test results.

A.5.5.4.2 Dry powder concentrates need be tested only for uniform corrosion at the maximum and minimum concentrations, as specified by the manufacturer. Ready-to-use products should be tested as received.

A.5.5.5.2 Common degreasers include all-purpose cleaners and dishwasher soaps. The chosen degreaser should be used for all comparative testing.

A.5.5.6.5 The jar lid should be firmly hand-tightened but not sealed. The intent of this requirement is to minimize evaporation of the solution while preventing a buildup of pressure. This level of tightness most closely replicates the storage of materials in service.

A.5.6.1 Intergranular corrosion is not permitted when the solution is delivered by aircraft.

A.6.1 Table A.6.1 provides fire test methods for specific hazards.

A.6.4 The Class A coal fire represents a challenging deep-seated fire with real life applications. For example, stored coal is subject to self-heating and potential combustion. The resulting fires are deep seated and difficult to extinguish.

During these tests, water and representative additives should be applied to the top of a suspended drum containing the coal fire. The flow rate of the water or water plus additive should be varied over successive tests utilizing a bracketing technique to determine the minimum flow rate required to extinguish the fire within 2 minutes of the start of the agent application.

Test Apparatus. This apparatus consists of a 208 L (55 gal) steel drum suspended 25 cm (10 in.) above a water collection pan. The top and bottom of the drum will be removed with a screen supported with an angle iron cross brace installed on the bottom of the drum to support the coal. The 10 cm (4 in.) gap between the elevation of the lip of the pan and the bottom of the drum will allow for the free flow air to supply the fuel combustion and to allow the water or water with additive to drain from the drum.

The drum should be filled with coal to a level 10 cm (4 in) from the top of the drum. The space at the top of the drum should prevent the overflow of the water or water with additive from the top of the drum. The coal to be utilized for these tests should come from the same source for all of the tests to be conducted to ensure that the variation in coal supply does not influence the evaluation. A consistent coal size should be used; for example, a range of 0.8 cm to 1.4 cm (0.3 to 0.6 in) "Buck" size. The coal pile should be ignited with a tubular heater inserted 20 cm (8 in) from the bottom of the coal layer. Thermocouples should be inserted into the coal to monitor the coal combustion.

The water or water with additive should be discharged from a pressurized 75 L (20 gal) tank. A quarter turn ball valve on the tank outlet should control the flow of the agent. The agent should flow from the tank and discharge onto the top of the coal pile from a nozzle suspended 27 cm (11 in.) above the top of the coal pile with a nozzle with a 90 degree full cone pattern. If a nozzle with a different spray pattern is used, then the height of the nozzle will be adjusted to achieve full coverage over the top surface of the coal pile. The tank should be pressurized with nitrogen utilizing a commercial nitrogen cylinder with a pressure regulator installed on the outlet of the cylinder.

The square water collection pan should have nominal dimensions of 71 cm (28 in.) on a side with a depth of 15 cm (6 in.) designed to contain the maximum of 75 L (20 gal) of water to be discharged during a test.

The apparatus is shown in Figure A.6.4.

Δ Table A.6.1 Fire Test Methods Applicable to Specific Hazards

Hazard	Applicable Fire Test Method	Minimum Application Rate
Fuel handling — coal — storage	Section 6.4	As determined by test
Fuel handling — coal — silo, bunkers, hoppers	Section 6.4	As determined by test
Fuel handling — coal — dust collector	Section 6.4	8.1 mm/min (0.20 gal/min/ft^2)
Fuel handling — coal — conveyor	Section 6.4	10.2 mm/min (0.25 gal/min/ft^2)
Boiler front: multiple oil-fired burners/igniters	Section 7.5	10.2 mm/min (0.25 gal/min/ft^2)
Regenerative air heaters	Section 7.5	24.4 mm/min (0.60 gal/min/ft^2)
Flue gas bag–type dust collectors	Section 7.5	8.1 mm/min (0.20 gal/min/ft^2)
Transformer–rectifier sets	Sections 7.2, 7.3, 7.4, 7.5[a]	10.2 mm/min (0.25 gal/min/ft^2)
Hydraulic control systems	Sections 7.2, 7.3, 7.4, 7.5[a]	As determined by test
Turbine–generator area	Sections 7.2, 7.3, 7.4, 7.5[a]	12.2 mm/min (0.30 gal/min/ft^2)
Lubricating oil lines	Sections 7.2, 7.3, 7.4, 7.5[a]	12.2 mm/min (0.30 gal/min/ft^2)
Lubricating oil reservoirs and handling equipment	Sections 7.2, 7.3, 7.4, 7.5[a]	As determined by test
Turbine–generator bearings	Sections 7.2, 7.3, 7.4, 7.5[a]	10.2 mm/min (0.25 gal/min/ft^2)
Emergency generators	Sections 7.2, 7.3, 7.4, 7.5[a]	10.2 mm/min (0.25 gal/min/ft^2)
Auxiliary boilers	Sections 7.2, 7.3, 7.4, 7.5[a]	10.2 mm/min (0.25 gal/min/ft^2)
Oil-filled transformer	Sections 7.2, 7.3, 7.4, 7.5[a]	10.2 mm/min (0.25 gal/min/ft^2)
Tire storage	To be determined	To be determined
Pressurized oil spray	Sections 7.2, 7.3, 7.4, 7.5[a]	As determined by test
Flammable liquid rack storage	Sections 7.2, 7.3, 7.4, 7.5[a]	As determined by test
Aircraft (group III hangars)	To be determined	To be determined
Aircraft (manual suppression of pool fuel fires)	Sections 7.2, 7.3, 7.4	As determined by test
Hay and straw	To be determined	To be determined
Exposure protection	Section 7.7[b]	As determined by test
Energized electrical cable	Section 8.2[c]	As determined by test

[a]Testing per Sections 7.2, 7.3, and 7.4 are for manual determination of manual firefighting effectiveness, while Section 7.5 is intended to evaluate effectiveness when used in a fixed system.

[b]Testing per Section 7.7 is for determination of effectiveness in rendering fuel spills non-reignitable during overhaul operations until they can be removed.

[c]Testing per Section 8.2 is intended to determine the safety of application of water additive solutions to equipment that may be energized. When equipment is de-energized, use appropriate extinguishing method for the remaining Class A or B hazard.

Test Procedure. The test procedure is as follows:

(1) The steel drum should be filled with coal to a level 10 cm (4 in) from the top of the drum and the tubular heater connected to the power supply.
(2) The agent tank should be filled with water or water plus additive and pressurized with nitrogen. The outlet of the tank should be connected to the discharge piping leading to the desired nozzle. The water collection pan should be located below the steel drum.
(3) The tubular heater should be energized and the thermocouples monitored for signs of combustion. The application of the water or water with additive should be started 1 minute after the observation of visible smoke above the coal pile.
(4) The water application should be stopped and the test concluded when there are no signs of continued combustion (smoke or raised temperatures).
(5) The duration of the water application and the application rate should be recorded.
(6) The steel drum and the water collection pan should then be emptied and dried in preparation for the next test.

Test Results. The minimum application rate required to cause extinguishment should be determined utilizing a bracketing technique. The determined application rate requirements determined for the additives could then be compared to that required for water alone to illustrate the performance enhancement due to the use of the additive.

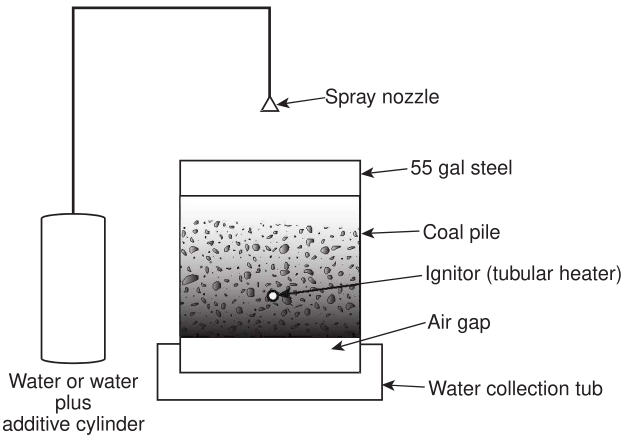


FIGURE A.6.4 Deep-Seated Fire Test Apparatus. ***(Source: Scheffey et al., 2013.)***

The primary challenge in using this apparatus is maintaining a consistent coal sizing through successive tests. Previous tests by the US Coast Guard [Schultz et al., 1990] have shown that penetration of the suppression agent throughout the pile is a key to effectiveness and is affected by the size of the coal briquettes utilized.

A.7.2 Although water additive solutions and Class B foams are required to pass Class B fire performance tests to obtain a listing, the tests are different. Some of the most important differences are as follows:

(1) The tested application rate for water additive solutions is different from the tested application rate for Class B foam solutions in NFPA 11.
(2) The burnback resistance time is 180 seconds for water additive solutions, compared to 360 seconds for foam solutions.
(3) The published application rate for water additive solutions is 5/3 the test application rate (rounded up) compared to 5/3 for protein and fluoroprotein foam and 5/2 for aqueous film-forming foam (AFFF) and film-forming fluoroprotein (FFFP).

A.7.2.9 Ghost flames or intermittent "flashovers" can occur. They are not to be considered a part of the burnback area unless sustained burning occurs for more than 30 seconds.

A.7.3 Although water additive solutions and Class B foam solutions are required to pass Class B fire performance tests to obtain a listing, the tests are different. Some of the most important differences are as follows:

(1) The tested application rate for water additive solutions in NFPA 18A is different from the tested application rate for Class B foam solutions in UL 162.
(2) The burnback or sealability requirements for water additive solutions are less than those for agents tested to UL 162.
(3) The application rate in NFPA 18A is 10.19 L/min/m^2, which is a 5/2 safety factor over the test application rate. This is the same safety factor as applied to AFFF and FFFP.

Experience with the extinguishment of fires in extreme depth such as tank or dike fires is limited, if any.

A.7.4.3 A slight adjustment in fuel flow is permitted to ensure that both top plates of the vertical cascade receive equal quantities of fuel flowing down both sides of the front vertical column of the cascade test device.

A.7.5 *Test Setup.* The Class B pool fire containment area should be 4.65 m^2 (50 ft^2) [2.15 m (7.07 ft) on a side]; the height of the pan should be 0.3 m (1.0 ft). The pan should be filled with diesel approximately 25 mm (1 in.) deep. The pan should be filled with water such that the freeboard height (i.e., the height between the top lip of the pan and the top of the fuel) is 203 mm (8.0 in.) The test pan should be self-leveling such that the free-board height remains relatively constant throughout the test. An elbow and pipe connected to the bottom of the pan should drain off the leveling water as fuel from the cascade and water from the sprinklers accumulates in the pan. Initially the pan should incorporate 0.96 L (0.25 gal) of heptane on top of the diesel as an accelerant to increase flame spread across the pool.

The test apparatus should be a cascade array, consisting of five inclined trays mounted above a 0.3 m (3.25 ft) square pan. The fuel should be discharged onto the top tray and allowed to flow down that tray to the tray below, which should be inclined in the opposite direction. Fuel should be discharged through a two pipe manifold; the topmost pipe should be connected to the fuel supply at one end and to the bottom pipe by three vertical pipes, one at the center and one near each end. The three connections are intended to balance the flow to the bottom pipe. A slit, 6.35 mm (0.25 in.) wide and 0.61 m (2.0 ft) long, in the bottom pipe allows the fuel to flow evenly onto the tray below. The fuel should flow successively down each of the inclined trays prior to reaching the bottom pan. The bottom pan should have a notch cut in the front of the pan to facilitate the flow of the fuel to the larger containment pan. The bottom pan of the fuel cascade should be initially filled with 25 mm (1.0 in.) of water and 4.5 L (1.2 gal) of diesel, with 0.05 gal of heptane as an accelerant.

The cascade apparatus should be centered within the containment pan. The containment pan should be filled with 51 mm (2 in.) of water.

A fuel flow rate of 7.6 L/min (2 gpm) should be used. The flow rate through the fuel system should be measured using a flow meter. Figure A.7.5(a) and Figure A.7.5(b) show general layouts of the test area and test setup.

A modified UL 162 sprinkler test should be used for this test. The parameters are as follows:

(1) Test pan — 4.65 m^2 (50 ft^2)(2.15 m × 2.15 m) (7.07 ft × 7.07 ft)
(2) Nozzle height — 4.57 mm (15 ft) to centerline of piping
(3) Sprinkler grid — four sprinklers located near the corners of the pan
(4) Cascade apparatus — centered in 4.65 m^2 (50 ft^2) test pan

Test Procedure. The test procedure is as follows:

(1) Ignite the fuel in the cascade pan.
(2) One minute after full involvement of the pan, initiate the fuel flow to the cascade.
(3) Thirty seconds after full involvement of the cascade as determined by visual observation, begin application of the water with additive.
(4) Stop the sprinkler system flow after the fire is extinguished or a minimum five minute application period has been completed, whichever comes first.

Test Results. The following criteria should be applied to determine successful extinguishment:

(1) No trays burning, fire just in cascade pan; or
(2) If bottom cascade pan extinguished, fire on just one tray

A.7.6 The characteristics of polar solvent fuels are such as to potentially render the Class B extinguishment and/or vapor mitigation test protocols for hydrocarbons inadequate. However, there does not currently exist sufficient information to specify appropriate extinguishment and/or vapor mitigation tests for these agents on polar solvents.

A.7.7.1 An emulsifying agent is one that is capable of rendering the fuel nonflammable by encapsulating the hydrocarbon molecules.

N **A.7.7.2.1(1)** To meet the 4.6 m^2 pan surface area, the round test pan should have a diameter of 770 mm, and the square test pan should be 690 mm by 690 mm.

A.7.7.3 The basic building block of an encapsulator agent is a spherical micelle. A spherical micelle is a molecular structure (i.e., molecular chemical cocoon, molecular vault) capable of encapsulating fuel molecules, thus separating the fuel from the oxygen on a chemical/molecular level and rendering the fuel nonflammable, nonignitable, and nonexplosive. Spherical micelles encapsulate fuel molecules regardless of whether the

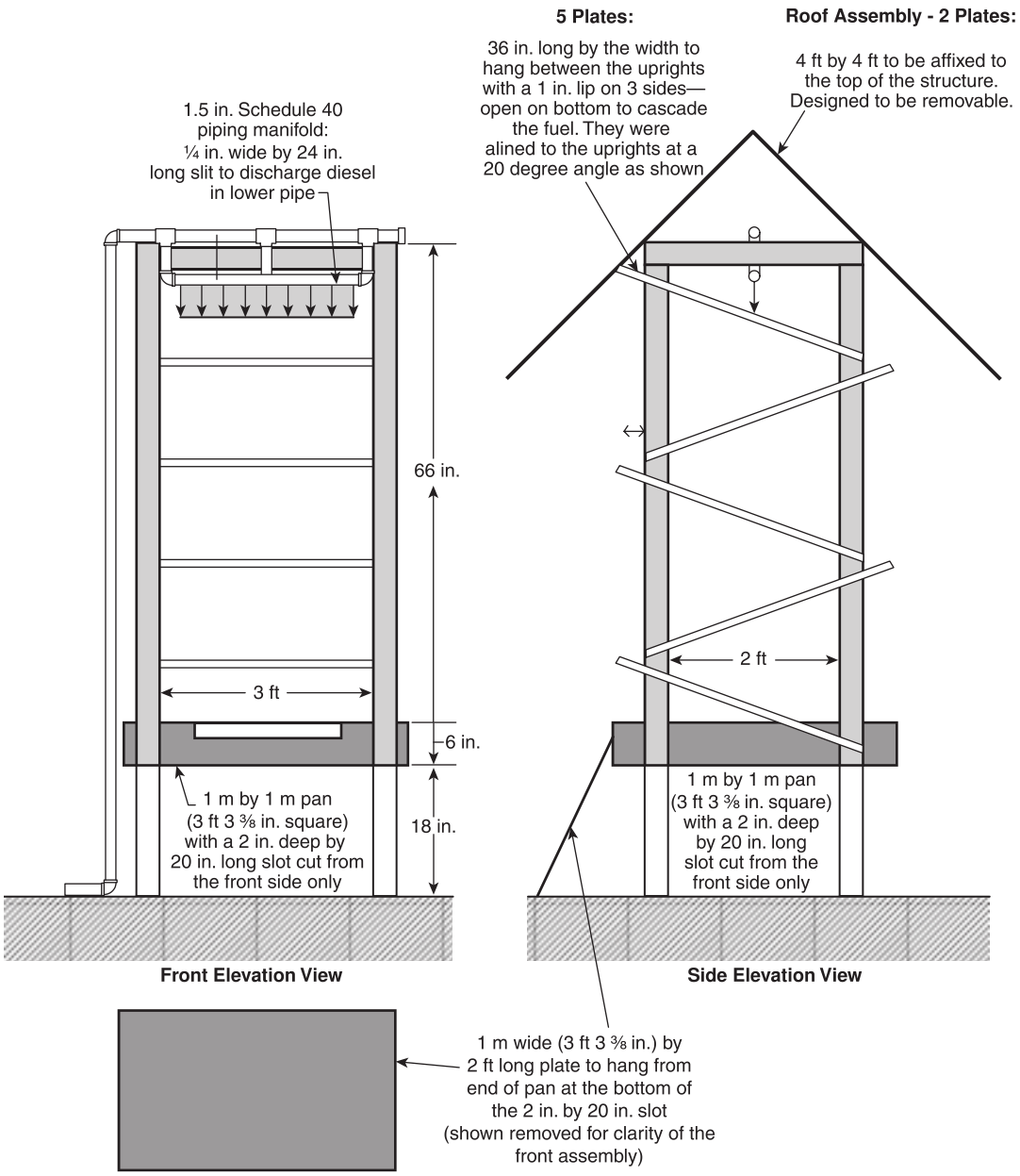


FIGURE A.7.5(a) Cascade Array. ***(Source: Scheffey et al., 2013.)***

fuel molecules are in the liquid phase or vapor phase. They can encapsulate a variety of fuels such as carbons and hydrocarbons (nonpolar and polar). While this test might at first appear to neutralize the flammability of the fuel, the test actually uses the fuel to determine whether an agent can form stable spherical micelles capable of the following:

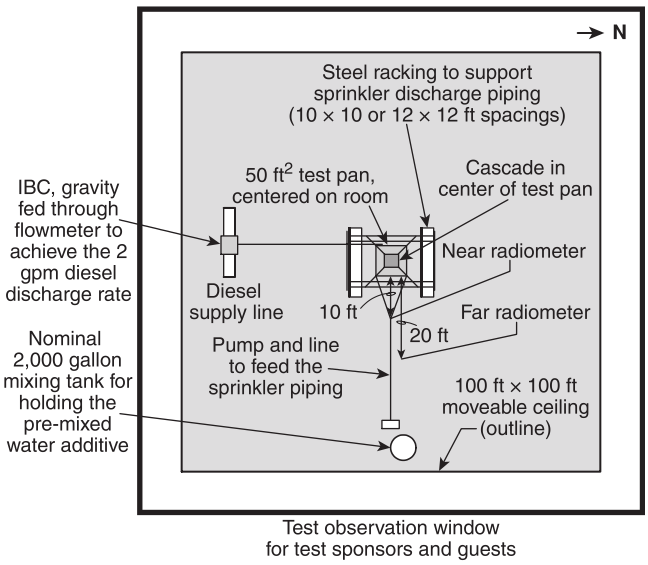
(1) Encapsulating the fuel and separating the fuel from the oxygen
(2) Remaining stable in the presence of high heat — the 1-minute ignition test
(3) Remaining stable in the presence of high heat over an extended period of time — the 2-hour ignition test

In the encapsulator — spherical micelle stability test, an agent could use the mix ratio in Table A.7.7.3 to document stable spherical micelle encapsulation of a fuel (heptane, ethanol blended fuel, etc.).

The agent's concentration proportioning rate, shown in the listing and on the label, would be the ratio of water additive/water. In this example, 1 part water additive/40 parts water = 2.5 percent.

To calculate the quantity of water additive solution needed for 100 percent encapsulation and neutralization of the fuel, the fuel neutralization ratio used is fuel/water. In this example, the ratio is 8 parts fuel/40 parts water, which reduces to 1 part fuel/5 parts water.

See A.4.3.6(1) on how these ratios are applied.



Δ FIGURE A.7.5(b) Test Setup. ***(Source: Scheffey et al., 2013.)***

N Table A.7.7.3 Encapsulator — Spherical Micelle Stability Test Sample

Item	Mix Ratio (Part)	US Units	SI Units
Water additive	1	1/8 US gal (16 oz)	500 ml
Fuel (7.7.2.2)	8	1 US gal	4 L
Water	40	5 US gal	20 L

Kinetic energy — Through agitation of contents with a 5 gpm (20 L/min) nozzle over a full 1-minute period.

N A.7.7.5 Since the ratio of water additive/water shown in Table 7.7.3 is 1 part water additive/40 parts water = 2.5 percent, the water additive can be listed as an acceptable encapsulator for the fuel tested at a water additive concentration/proportion rate of not less than 2.5 percent and water additive solution not less than 2.5 percent.

A.7.8 Appropriate test criteria have not been developed and defined.

Δ A.8.2.1.1 See UL 711/ULC CAN-S508.

A.8.2.1.2 See Table A.8.2.1.2.

A.8.2.1.3 Per *NFPA 70E* regarding the effects of current on the human body, 0.5 mA is the perception threshold level, so a leakage half that value is required to pass the test.

A.8.2.5 Trained firefighters include the following:

(1) Firefighters meeting the qualifications outlined in NFPA 1001
(2) Private brigades who are qualified in accordance with NFPA 1081
(3) Electrically qualified workers as defined by 29 CFR 1910.332(b)(3)
(4) Firefighters of equivalent qualifications acceptable to the authority having jurisdiction

Δ Table A.8.2.1.2 R-7 Alternative Minimum Approach Distances for Voltages of More than 72.5 kV[1,2,3]

Voltage Range Phase to Phase (kV)	Phase-to-Ground Exposure	
	m	ft
72.6 to 121.0	1.13	3.71
121.1 to 145.0	1.3	4.27
145.1 to 169.0	1.46	4.79
169.1 to 242.0	2.01	6.59
242.1 to 362.0	3.41	11.19
362.1 to 420.0	4.25	13.94
420.1 to 550.0	5.07	16.63
550.1 to 800.0	6.88	22.57

[1]Employers may use the minimum approach distances in this table provided the worksite is at an elevation of 900 m (3,000 ft) or less. If employees will be working at elevations greater than 900 m (3,000 ft) above mean sea level, the employer shall determine minimum approach distances by multiplying the distances in this table by the correction factor in Table 4 corresponding to the altitude of the work.
[2]Employers may use the phase-to-phase minimum approach distances in this table provided that no insulated tool spans the gap and no large conductive object is in the gap.
[3]The clear live-line tool distance shall equal or exceed the values for the indicated voltage ranges.
Source: Table R-7 of 29 CFR 1910.269.

A.8.3 Section 8.3 addresses the ability of water additive solutions to be evaluated for use in manual firefighting operations to suppress Class C fires or on fires impinged by live electrical sources.

A.8.3.4 Water additive solutions made with synthetic seawater, as defined by ASTM D1141, can also be tested if such usage is specified by the manufacturer.

A.8.3.6.2 See Figure A.8.3.6.2, which illustrates a typical electrical substation disconnect switch.

FIGURE A.8.3.6.2 138 kV Substation Disconnect Switch. ***(Courtesy of ConEdison.)***

A.8.3.6.3 Disconnect switches designed for target voltages above 138 kV, such as 345 kV and 500 kV, are ideal because their designs consider insulation from a ground reference via the insulators.

A.8.3.6.4 The wire inserted into the nozzle ensures contact is made with the stream of solution being tested.

A.8.3.6.5 See Figure A.8.3.6.5, which illustrates a multimeter arrangement.

A.8.3.6.7 The test stand that will receive the discharge appliance should be constructed of dielectric material.

A.8.3.6.7.1 The rating table establishes categories to define voltage, the operating safe standoff distance, and the test standoff distance (75 percent of the operating standoff distance) for common electrical equipment thresholds.

A.8.4 See Figure A.8.4, which illustrates the configuration for the arc conductor.

A.8.4.3.3 Water additive solutions made with synthetic seawater, as defined by ASTM D1141, can also be tested if such usage is specified by the manufacturer.

A.8.4.3.6 The purpose of the maximum 7.6 m (25 ft) cable length is to limit resistance.

A.8.4.3.7 See Figure A.8.4.3.7, which illustrates a concrete box design.

A.8.4.3.11 The purpose of measuring combustible gases continuously from 2 minutes prior to the inception of the cable fault through the application of the products is to record the evolution and production of combustible gases created by the burning insulation on the jacket of the cable. The production of combustible gases is the cause of secondary explosions in electrical fires.

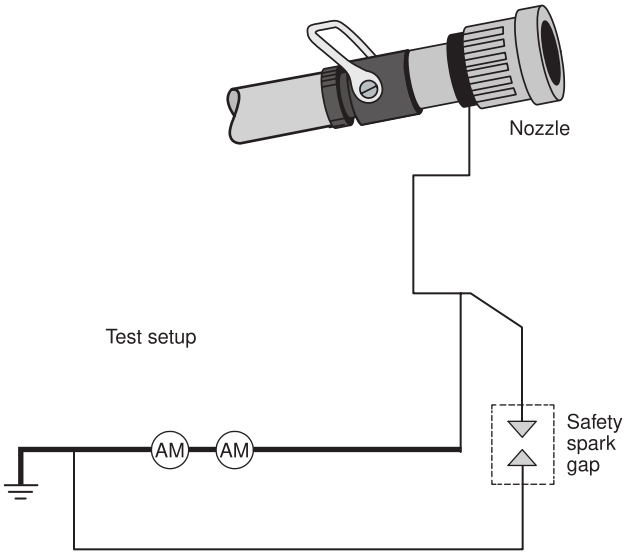


FIGURE A.8.3.6.5 Multimeter Arrangement in the Current Measuring Circuit. ***(Source: ConEdison.)***

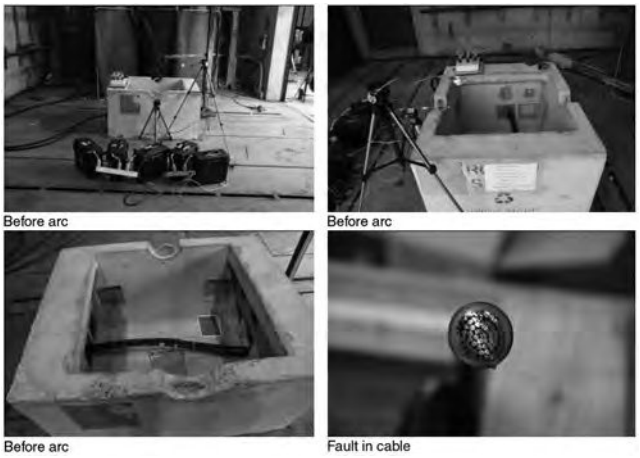


FIGURE A.8.4 Arc Conductor Test Configuration. ***(Courtesy of GelTech Solutions, Kinectrics Report, "Arc Performance & Byproducts of FireIce — Summary of Air Sampling Results.")***

A.8.4.3.12 The arc is considered to have been suppressed through observation and verified by the use of calorimetry.

A.8.4.3.13(2) See Figure A.8.4.3.13(2), which illustrates the test report format.

A.8.4.3.13(5) Video should be in real time and in high speed.

N **A.9.2.1** Class D metals, other than solid-state metals, such as sodium, potassium, and other alloy metals are currently outside the scope of this document.

N **A.9.2.7** Overfilling the secondary containment could result in a violation of local, state, and federal environmental laws.

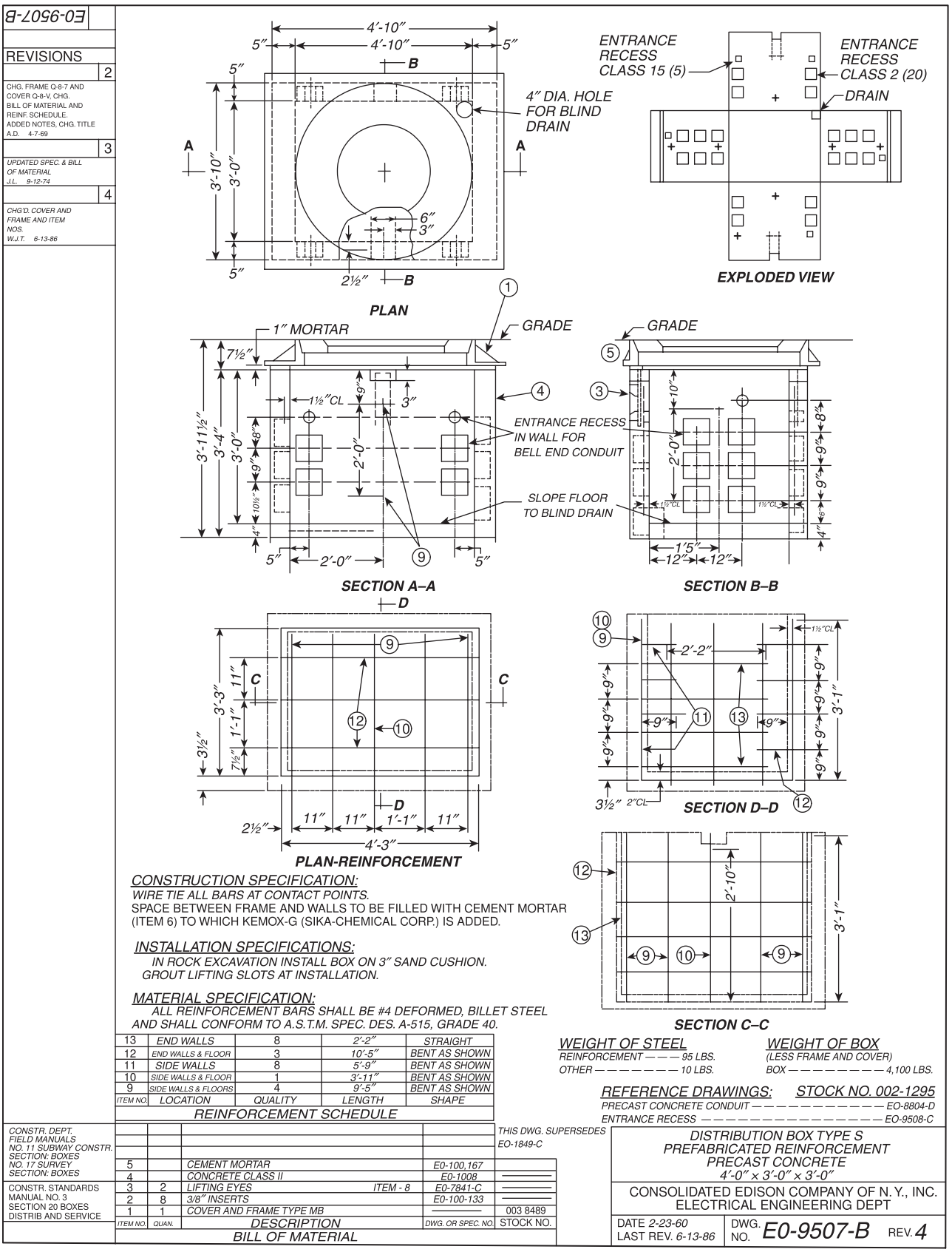
N **A.9.2.12** Class D tests could be conducted indoors if the test facility has appropriate safeguards to conduct the test safely indoors.

A.10.1.1 Water additive concentrate containers should conform to the United Nations Performance Based Packaging Standards as codified under US Department of Transportation Regulations, 49 CFR 178.600.

A.10.3 For a completed label example, see Figure A.10.3.

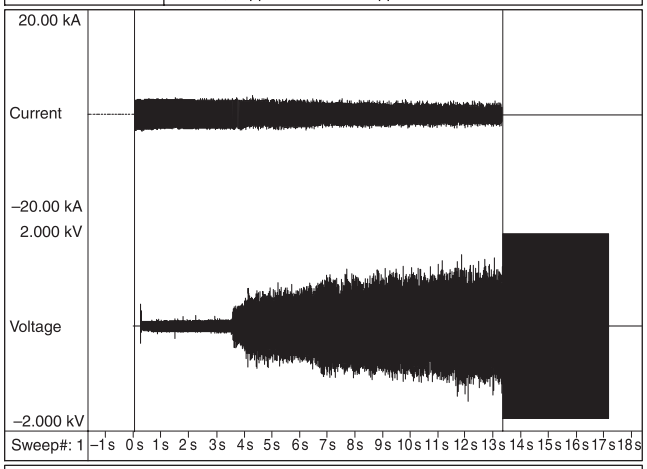
A.11.1.1 This standard does not specify the method whereby the water additive concentrate is added to water. The solution can be premixed in tanks or can result from the water additive concentrate being brought into contact with water by any suitable proportioning device, provided said device is approved in accordance with applicable standards.

A.11.2.2 Where such equipment is also used to take suction from a hydrant supplied by potable water, extra care should be exercised to prevent contamination of such potable water supplies with the water additive concentrate or solution.



Δ FIGURE A.8.4.3.7 Concrete Box Drawing. ***(Source: ConEdison.)***

Test description:	Fire and smoke suppression of electrical fire in concrete vault
Sample description:	- - -
Shot information:	Shot #1, copper cables, no suppression



Calculated values between cursors			
Current total RMS	1.670 kA		
Current peak	3.405 kA		
Terminal voltage	500.4 V		
Duration (cycles of 60 Hz)	800 cycles		
Duration (time)	13.32 s		

FIGURE A.8.4.3.13(2) Illustration of the Test Report Format. ***(Source: ConEdison.)***

Application	Listed Concentration	Listed Flow Rate	Listing Agency
Spill fire	3%	6.89 L/min/m^2	UL
Pool fire	6%	10.19 L/min/m^2	UL
Fuel in depth fire	Not listed	Not listed	—
3D aviation	3%	43.15 L/min	UL
3D industrial	3%	64.73 L/min	UL
Polar solvent	Not listed	Not listed	—
Emulsification	See listing	See listing	UL

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Δ FIGURE A.10.3 Completed Label Example.