

NFPA[®]

18A

**Standard on
Water Additives
for Fire Control
and Vapor Mitigation**

2017



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NFPA® 18A

Standard on

Water Additives for Fire Control and Vapor Mitigation

2017 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 November 11, 2016, with an effective date of December 1, 2016, and supersedes all previous editions.

This edition of NFPA 18A was approved as an American National Standard on December 1, 2016.

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 include 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 has undergone extensive technical and editorial revision. Technical changes include 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 include updating the structure of the standard to further comply with the *Manual of Style for NFPA Technical Committee Documents*.



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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

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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NFPA 18A

Standard on

Water Additives for Fire Control and Vapor Mitigation

2017 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. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex E. 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 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 and Class B 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 fires in Class A and Class B fuels.

1.3* Application. This standard applies to water additives utilized in preventing or reducing the spread of fire in Class A and Class B fuels.

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.

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

NFPA 10, *Standard for Portable Fire Extinguishers*, 2017 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2016 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 2016 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 2017 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2017 edition.

NFPA 70E®, *Standard for Electrical Safety in the Workplace®*, 2015 edition.

NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, 2013 edition.

NFPA 1081, *Standard for Industrial Fire Brigade Member Professional Qualifications*, 2012 edition.

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

2.3 Other Publications.

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*, 2012b.

ASTM D97, *Standard Test Method for Pour Point of Petroleum Products*, 2012.

ASTM D1141, *Standard Practice for the Preparation of Substitute Ocean Water*, 2013.

ASTM D1293, *Standard Test Methods for pH of Water*, 1999 (2012).

ASTM D2196, *Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer*, 2015.

ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*, 2010.

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

ASTM G1, *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens*, 2011.

ASTM G31, *Standard Guide for Laboratory Immersion Corrosion Testing of Metals*, 2012.

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

OPPTS 835.3110, *Ready Biodegradability*, Section M, *CO₂ Evolution (Modified Sturm) Test*, Fate, Transport, and Transformation Test Guidelines, January 1998.

OPPTS 850.1075, *Fish Acute Toxicity Test*, Freshwater and Marine, Ecological Effects Test Guidelines, 1996.

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

OPPTS 870.1200, *Acute Dermal Toxicity*, Health Effects Test Guidelines, 1998.

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

OPPTS 870.2500, *Acute Dermal Irritation*, Health Effects Test Guidelines, 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*, 2005, Technical Corrigendum 1:2006.

2.3.4 NACE Publications. NACE International, 1440 South Creek Drive, Houston, TX 77084-4906.

NACE/ASTM TM0169 G0031 12A, *Standard Guide for Laboratory Immersion Corrosion Testing of Metals*, 2012.

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

ANSI/UL 162, *Foam Equipment and Liquid Concentrates*, 1994, revised 2015.

ANSI/UL 711/CAN/ULC S508, *Rating and Fire Testing of Fire Extinguishers*, 2004, revised 2013.

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

ULC S560, *Category 3 Aqueous Film-Forming Foam (AFFF) Liquid Concentrates*, 2009.

2.3.7 U.S. Government Publications. U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Title 29, Code of Federal Regulations, Part 1910.332, Subpart S, "Training," Occupational Safety and Health Standards.

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."

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

2.3.8 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*, 2017 edition.

NFPA 36, *Standard for Solvent Extraction Plants*, 2017 edition.

NFPA 1145, *Guide for the Use of Class A Foams in Fire Fighting*, 2017 edition.

NFPA 1150, *Standard on Foam Chemicals for Fires in Class A Fuels*, 2017 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 phrase “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 of water additive solution applied over a specified period of time.

3.3.2 Biodegradability. A measure of the decomposition of organic matter through the action of microorganisms. [1150, 2017]

3.3.3 Class A Fire. A fire in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics. [10, 2017]

3.3.4* Class B Fire. A fire in flammable liquids, combustible liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases. [10, 2017]

3.3.5 Class C Fire. Class C fires are fires that involve energized electrical equipment.

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

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

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

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

3.3.10 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.

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

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

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

3.3.14* 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.

3.3.15 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.

3.3.16* Handline. A hose and nozzle that can be held and directed by hand.

3.3.17 Hydrocarbon. A chemical substance consisting of only hydrogen and carbon atoms. [36, 2017]

3.3.18 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, 2011]

3.3.19 LC₅₀ (Lethal Concentration₅₀). 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, 2017]

3.3.20 LD₅₀ (Lethal Dosage₅₀). 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, 2017]

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

3.3.22 Miscibility. The property of being capable of mixing in any ratio without separation into phases. [1150, 2017]

3.3.23 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.

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

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

3.3.26 Surface Tension. The elastic-like force at the surface of a liquid, which tends to minimize the surface area, causing drops to form. [1150, 2017]

3.3.27 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.

3.3.28 Three-Dimensional 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.

3.3.29* 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.

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

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

Chapter 4 Uses and Limitations

4.1 General.

4.1.1 Water additive concentrate for fire fighting shall be listed and approved by the authority having jurisdiction.

4.1.2 Water additive concentrate shall be mixed only with water.

4.2 Limitations.

4.2.1 General. The use of water additive solution shall be limited to those applications identified by the manufacturer's listing and Section 4.2.

4.2.2 Water-Reactive Chemicals. 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.

4.2.3 Hazards. Water additives shall be listed for one or more of the following applications:

- (1) Fuel handling — coal — storage
- (2) Fuel handling — coal — silo, bunkers, hoppers
- (3) Fuel handling — coal — dust collector
- (4) Fuel handling — coal — conveyor
- (5) Boiler front: multiple oil-fired burners/igniters
- (6) Regenerative air heaters
- (7) Flue gas bag-type dust collectors
- (8) Transformer-rectifier sets
- (9) Hydraulic control systems
- (10) Turbine-generator area
- (11) Lubricating oil lines
- (12) Lubricating oil reservoirs and handling equipment
- (13) Turbine-generator bearings
- (14) Emergency generators
- (15) Auxiliary boilers
- (16) Oil-filled transformer
- (17) Tire storage
- (18) Pressurized oil spray
- (19) Manual fire fighting operations
- (20) Flammable liquid rack storage
- (21) Aircraft (group III hangars)
- (22) Aircraft (manual suppression of pool fuel fires)
- (23) Hay and straw
- (24) Exposure protection
- (25) Energized electrical cable
- (26) Other applications as tested and as approved by the authority having jurisdiction

4.2.4 Class B Fires.

4.2.4.1 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.

4.2.4.2* 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 (vegetable or animal oils and fats) unless specifically listed for this hazard.

4.2.5* Class C Fires. Water additive solutions shall be evaluated for use on Class C fires in accordance with Chapter 8.

4.2.6* Class D Fires. Water additive solution shall not be used on Class D fires unless specifically listed for that purpose.

4.3* Compatibility of Water Additive Concentrate and Solutions.

4.3.1 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.

4.3.2 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.

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

4.3.4 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.

4.4 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.

5.2.1.1 Water additive concentrates and water additive solution prepared at the maximum concentration specified for use by the manufacturer shall be tested in accordance with the following U.S. EPA OPPTS tests or an equivalent test procedure that is recognized by the authority having jurisdiction where the water additive is to be used:

- (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

5.2.1.2* 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.

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 U.S. EPA 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 $\pm$ 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 $12^{\circ}\text{C} \pm 1^{\circ}\text{C}$.

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.

5.2.3.2 The biodegradability of the concentrate shall be determined in accordance with EPA OPPTS 835.3110 Section M, CO_2 evolution test (modified Sturm test) 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 $60 \text{ rpm} \pm 10 \text{ rpm}$.

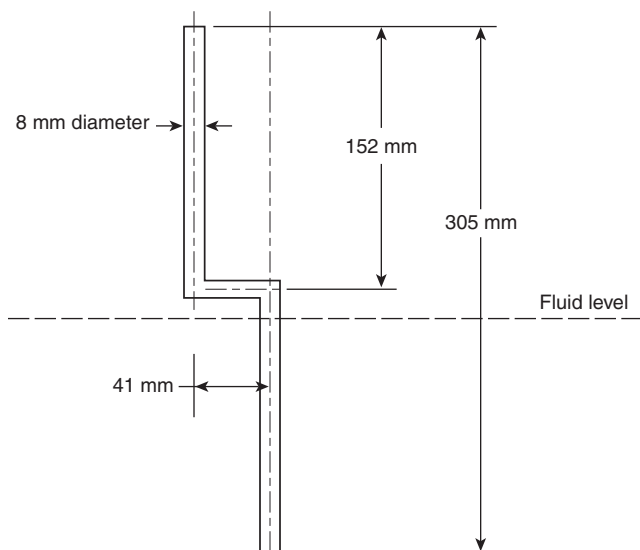
5.3.2.2.5 The required amount of concentrate conditioned to the test temperature shall be added to the beaker of water within 2 seconds.

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.

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

Water Additive Temperature	Water Temperature
$^{\circ}\text{C}$	$^{\circ}\text{C}$
4 ± 1	21 ± 1
21 ± 1	21 ± 1
4 ± 1	4 ± 1
21 ± 1	4 ± 1



Note: All measurements are approximate.

FIGURE 5.3.2.2.3 Stirrer Shaft for Miscibility Test.

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 $18^{\circ}\text{C} \pm 2.7^{\circ}\text{C}$ 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 $41^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for 30 continuous days.

5.4.1.4.2 At the end of 30 days, Sample 1 shall be removed from the $41^{\circ}\text{C} \pm 3^{\circ}\text{C}$ environment and immediately stored at $21^{\circ}\text{C} \pm 2^{\circ}\text{C}$ 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 $41^{\circ}\text{C} \pm 3^{\circ}\text{C}$ 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 $-10^{\circ}\text{C} \pm 1^{\circ}\text{C}$.

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 $-10^{\circ}\text{C} \pm 1^{\circ}\text{C}$ environment and then placed immediately in an environment of $21^{\circ}\text{C} \pm 2^{\circ}\text{C}$ 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 $-10^{\circ}\text{C} \pm 1^{\circ}\text{C}$ for 30 continuous days.

5.4.1.6.2 At the end of the 30 days, Sample 3 shall be removed from the $-10^{\circ}\text{C} \pm 1^{\circ}\text{C}$ environment and immediately placed at a temperature of $21^{\circ}\text{C} \pm 2^{\circ}\text{C}$ 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 $21^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

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.

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
<i>mils per year</i>													
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 ^a ground-based application	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.

^aMagnesium uniform corrosion tests shall be performed for performance information. Intergranular corrosion tests are not required on aluminum or magnesium.

^bIntergranular corrosion tests shall be performed on aluminum and magnesium coupons; no intergranular corrosion is allowed.

^cIntergranular 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.

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 Standard Test Method 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.

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 ₃ PO 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/ASTM TM0169.

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.

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/cm³ (lb/in.³)] as follows: 4130 steel = 7.86 g/cm³ (0.28 lb/in.³); yellow brass = 8.53 g/cm³ (0.3 lb/in.³); 2024-T3 aluminum = 2.77 g/cm³ (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.

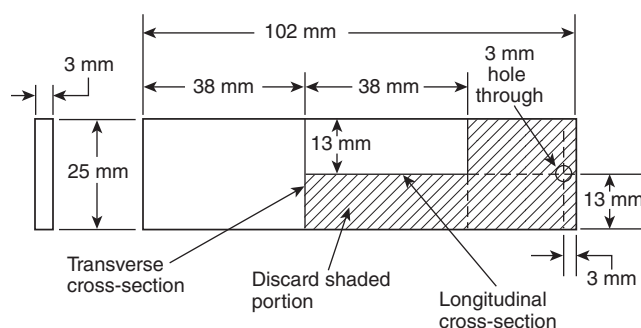


FIGURE 5.6.3 Intergranular Corrosion Test.