

NFPA® 412

Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment

2014 Edition



NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
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NFPA® 412

Standard for

Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment

2014 Edition

This edition of NFPA 412, *Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment*, was prepared by the Technical Committee on Aircraft Rescue and Fire Fighting. It was issued by the Standards Council on May 28, 2013, with an effective date of June 17, 2013, and supersedes all previous editions.

This edition of NFPA 412 was approved as an American National Standard on June 17, 2013.

Origin and Development of NFPA 412

Work on this material started in 1955 when the NFPA Subcommittee on Aircraft Rescue and Fire Fighting (as then constituted) initiated a study on methods of evaluating aircraft rescue and fire-fighting vehicles. A tentative text was adopted by the Association in 1957, and a revised text was officially adopted in 1959. Revisions were made in 1960, 1964, 1965, 1969, 1973, and 1974. With the introduction of new types of foam liquid concentrates over the years for this specialized service, the text has been broadened to cover these concentrates.

In 1987, the standard was completely revised to bring it into conformance with the NFPA *Manual of Style* and to refine the test methods.

The 1993 edition of the standard established a single test method for expansion and drainage for all foams and also added information on using the conductivity meter for determining foam solution concentration. Problems with the apparatus of the single test method in the 1993 edition and with accurately determining results indicated a need to reinstate the simpler method for the 1998 edition as an alternative method. The simpler method is also in general field use.

The standard was revised for the 2003 edition with only minor editorial changes.

For the 2009 edition, the Technical Committee reaffirmed the requirements of the 2003 edition, and minor editorial changes were made.

For the 2014 edition, the Technical Committee has revised many of the requirements regarding foam and the testing and test method requirements for foam. These updated requirements allow for a broader use and application of foams along with the methods and equipment that are used to evaluate the foam. The Technical Committee also made several changes according to the *Manual of Style for NFPA Technical Committee Documents*, and updated references to NFPA and non-NFPA documents.

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Duane F. Kann, *Chair*

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John W. McDonald, *Secretary*

U.S. General Services Administration, VA [E]

Keith W. Bagot, U.S. Federal Aviation Administration, NJ [RT]

Peter H. Bordeleau, U.S. Marine Corps, TX [C]

Charles Cinquemani, Dallas/Fort Worth International Airport Board, TX [C]

Rep. Airports Council International-North America

Ralph Colet, JRI Inc., CA [M]

Ross A. Davidson, U.S. Department of the Navy, CA [C]

Graeme Day, BAA Ltd., United Kingdom [C]

Hanh Deniston, Metropolitan Washington Airports Authority, VA [L]

Rep. International Association of Fire Fighters

Fred B. Goodnight, Amerex Corporation, AL [M]

Rep. Fire Equipment Manufacturers' Association

Owen Healey, United Kingdom Civil Aviation Authority, United Kingdom [E]

Mark S. Lawler, Omaha Airport Authority, NE [L]

Rep. Aircraft Rescue & Fire Fighting Working Group, Inc.

Stephen Listerman, Cincinnati/Northern Kentucky

International Airport Fire Department, OH [C]

John Anderson Maddox, Lakeland Fire Department, FL [U]

Graydon L. Matheson, King County Sheriff's Office-ARFF Division, WA [U]

Robert C. Mathis, The Boeing Company, WA [M]

John E. McLoughlin, Fire Research Corporation, MO [M]

Paul S. Meyer, Hartsfield-Jackson Atlanta International Airport, GA [C]

Kevin J. Petit, Akron Brass Company, OH [M]

Pam L. Phillips, Port Authority of New York & New Jersey, NJ [C]

Rep. American Association of Airport Executives

Danny M. Pierce, ARFF Solutions, CA [SE]

James E. Podolske, Jr., U.S. Department of the Air Force, FL [C]

Joseph L. Scheffey, Hughes Associates, Inc., MD [SE]

Jason Shively, Oshkosh Corporation, WI [M]

Jeremy Souza, Rhode Island Airport Corporation, RI [E]

Dirk Steyn, E-One, Inc., FL [M]

Marc S. Tonnacliff, U.S. Federal Aviation Administration, DC [E]

Dean D. Ulrich, Los Angeles City Fire Department, CA [U]

Pierre Voisine, National Defence Department, Canada, Canada [C]

Alternates

Abdulrahman A. Y. Alsaadi, Department of Civil Aviation, United Arab Emirates [U]

(Voting Alt. to Dubai Civil Aviation Dept. Rep.)

Alan Black, Dallas/Fort Worth International Airport Board, TX [C]

(Alt. to C. Cinquemani)

Ralph B. Colet, JRI Inc., CA [M]

(Alt. to R. Colet)

Bradford Colton, American Pacific Corporation, NV [M]

(Alt. to F. B. Goodnight)

Robert L. Darwin, Jacobs Technology, VA [C]

(Alt. to R. A. Davidson)

Richard L. James, III, Hartsfield-Jackson Atlanta International Airport, GA [C]

(Alt. to P. S. Meyer)

Ronald E. Jones, E-One, Inc., FL [M]

(Alt. to D. Steyn)

David J. Krajnak, KME Fire Apparatus, PA [M]

(Voting Alt. to FAMA Rep.)

Randy J. Krause, Port of Seattle Fire Department, WA [U]

(Voting Alt. to IAFC Rep.)

Dana Larsen, Los Angeles City Fire Department, CA [U]

(Alt. to D. D. Ulrich)

William K. Major, Buffalo Niagara International Airport Fire Department, NY [L]

(Voting Alt.)

Douglas C. Mangels, Denver Fire Department, CO [L]

(Alt. to M. S. Lawler)

Steven Schwartz, Oshkosh Corporation, WI [M]

(Alt. to J. Shively)

Nicholas M. Subbotin, U.S. Federal Aviation Administration, NJ [RT]

(Alt. to K. W. Bagot)

Nonvoting

L. M. Krasner, Medfield, MA [SE]

(Member Emeritus)

Thomas J. Lett, Albuquerque Fire & Safety Associates, NM [SE]

(Member Emeritus)

Francois Villard, Fire Safety Security Crisis Management Training, Switzerland [SE]

Kendall Holland, NFPA Staff Liaison

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Committee Scope: This Committee shall have primary responsibility for documents on aircraft rescue and fire-fighting services and equipment, for procedures for handling aircraft fire emergencies, and for specialized vehicles used to perform these functions at airports, with particular emphasis on saving lives and reducing injuries coincident with aircraft fires following impact or aircraft ground fires. This Committee also shall have responsibility for documents on aircraft hand fire extinguishers and accident prevention and the saving of lives in future aircraft accidents involving fire.



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NFPA 412

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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 C. 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 C.

Chapter 1 Administration

1.1 Scope. This standard establishes test procedures for evaluating the foam fire-fighting equipment installed on aircraft rescue and fire-fighting vehicles designed in accordance with NFPA 414.

1.2 Purpose. The tests specified in this standard provide procedures for the evaluation of foam fire-fighting equipment in the field to determine compliance with NFPA 414 and NFPA 403.

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 403, *Standard for Aircraft Rescue and Fire-Fighting Services at Airports*, 2014 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire-Fighting Vehicles*, 2012 edition.

2.3 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2010 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 Shall. Indicates a mandatory requirement.

3.2.2 Should. Indicates a recommendation or that which is advised but not required.

3.2.3 Standard. A document, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and which 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 *Manual of Style for NFPA Technical Committee Documents*.

3.3 General Definitions.

3.3.1* Foam. A stable aggregation of bubbles of lower density than oil or water. [11, 2010]

3.3.1.1* Alcohol-Resistant Foam Concentrate. A concentrate used for fighting fires on water-soluble materials and other fuels destructive to regular, AFFF, or FFFP foams, as well as for fires involving hydrocarbons. [11, 2010]

3.3.1.2* Aqueous Film-Forming Foam (AFFF) Concentrate. A concentrate based on fluorinated surfactants plus foam stabilizers to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors and usually diluted with water to a 1 percent, 3 percent, or 6 percent solution. [11, 2010]

3.3.1.3* Film-Forming Fluoroprotein (FFFP) Foam Concentrate. A protein-foam concentrate that uses fluorinated surfactants to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors. [11, 2010]

3.3.1.4 Fluoroprotein (FP) Foam. A protein-based foam concentrate, with added fluorochemical surfactants, that forms a foam showing a measurable degree of compatibility with dry chemical extinguishing agents and an increase in tolerance to contamination by fuel.

3.3.1.5 Protein (P) Foam. A protein-based foam concentrate that is stabilized with metal salts to make a fire-resistant foam blanket.

3.3.2* Foam Concentrate. A concentrated liquid foaming agent as received from the manufacturer. [11, 2010]



3.3.3 Foam Drainage Time (Quarter Life). The time in minutes that it takes for 25 percent of the total liquid contained in the foam sample to drain from the foam.

3.3.4 Foam Expansion. The ratio between the volume of foam produced and the volume of solution used in its production.

3.3.5 Foam Pattern. The ground area over which foam is distributed during the discharge of a foam-making device.

3.3.6 Foam Solution. The solution that results when foam concentrate and water are mixed in designated proportions prior to aerating to form foam.

3.3.7 Foam Stability. The degree to which a foam resists spontaneous collapse or degradation caused by external influences such as heat or chemical action.

3.3.8 Foam Weep. That portion of foam that is separated from the principal foam stream during discharge and falls at short range.

3.3.9 Heat Resistance. The property of a foam to withstand exposure to high heat fluxes without loss of stability.

3.3.10 Testing.

3.3.10.1 Input-Based Testing. Testing the foam solution by measuring the flow rate or volume of concentrate, or suitable substitute for concentrate, and comparing this flow rate or volume to the flow rate or volume of water used, then using those two numbers to calculate the proportions of concentrate and water in the foam solution.

3.3.10.2 Output-Based Testing. Testing the foam solution by collecting a sample of the solution after aerating and dispensing it, and using instruments and calculations to determine the sample's proportions of concentrate and water in the foam solution.

Chapter 4 Aircraft Rescue and Fire-Fighting Vehicle Foam Production Performance Testing

4.1 Foam System Performance Tests.

4.1.1 In addition to manufacturers' performance testing, ARFF vehicles shall be tested on a schedule set by the AHJ to meet the following criteria:

- (1) Expansion ratio
- (2) Drainage 25 percent
- (3) Proportioning
- (4) Distribution pattern

4.2 Turret Nozzles, Ground Sweep Nozzles, and Hand Line Nozzles.

4.2.1 The foam distribution patterns shall meet the requirements of NFPA 414 when tested as specified in Section 6.4 or 6.5 of this standard.

Chapter 5 Performance Criteria

5.1 Expansion Ratio and Drainage Time Requirements. Foams shall be tested as specified in 6.3.2 and 6.3.3 of this standard and meet at least the performance requirements specified in Table 5.1.

Table 5.1 Foam Quality Requirements

| Foam Agents | Minimum Expansion Ratio | Minimum Solution 25% Drainage Time in Minutes | |
|--------------------------------|-------------------------|---|---------------|
| | | Test Method A | Test Method B |
| AFFF or FFFP air-aspirated | 5:1 | 3 | 2.25 |
| AFFF or FFFP non-air-aspirated | 3:1 | 1 | 0.75 |
| Protein | 8:1 | N/A | 10 |
| Fluoroprotein | 6:1 | N/A | 10 |

5.1.1 The foam system shall be tested as specified in 6.3.2 and 6.3.3 of this standard and meet the performance requirements specified in Table 5.1.

5.2 Foam Solution Concentration.

5.2.1* For nominal 6 percent concentrates, the concentration shall be between 5.5 percent and 7.0 percent for turret and ground sweep nozzles and between 5.5 percent and 8.0 percent for hand line and undertruck nozzles.

5.2.2 For nominal 3 percent concentrates, the concentration shall be between 2.8 percent and 3.5 percent for turret and ground sweep nozzles and between 2.8 percent and 4.0 percent for hand line and undertruck nozzles.

5.2.3 For nominal 1 percent concentrates, the concentration shall be between 1.0 percent and 1.3 percent for all nozzles.

Chapter 6 Test Methods and Calculations

6.1 Preparation for Testing. The following general preparations shall be made prior to conducting concentration, expansion/drainage, and pattern testing:

- (1) The vehicle water and foam systems shall be verified to be operational.
- (2) The pressure and flow characteristics of each vehicle outlet shall be verified to be in accordance with NFPA 414.
- (3) The piping systems shall be flushed.
- (4)*For output-based testing, a sample of foam concentrate from the vehicle concentrate tank shall be obtained to form the baseline for concentration determinations and to determine whether the agent concentrate in the vehicle has been contaminated.
- (5) This sample shall be compared with a virgin sample of the same concentrate from a new foam container from the same manufacturer.

6.2 Foam Solution Concentration Determination.

6.2.1* Foam solution concentration shall be determined using one of the following methods as described in 6.2.2, 6.2.3, or 6.2.4.

6.2.1.1 When testing foam concentration from vehicles, the lowest flow rate outlet shall be tested first.

6.2.1.2 One handheld refractometer or one handheld conductivity meter suitable for the foam concentrate being tested shall be used for the methods described in 6.2.2 or 6.2.3.

6.2.1.3 Method B (in 6.2.3) shall be used only when using a refractometer.

6.2.1.4 Refractive index readings shall be taken by placing a few drops of solution on the refractometer prism, closing the cover plate, and observing the scale reading at the dark field intersection.

6.2.1.5 Alternatively, if using conductivity, the probe shall be dipped into the sample and the digital scale read.

6.2.2* Method A (Output-Based Testing Using a Refractometer or Conductivity Meter). A calibration curve shall be prepared using the apparatus and procedure in 6.2.2.1 and 6.2.2.2.

6.2.2.1 Apparatus. In preparing the calibration curve, the following apparatus shall be used:

- (1) Three 3.381 fl oz (100 mL) graduates
- (2) One measuring pipette [0.338 fl oz (10 mL capacity)]
- (3) One 3.381 fl oz (100 mL) beaker
- (4) One 16.907 fl oz (500 mL) beaker

6.2.2.2 Procedure.

6.2.2.2.1 Using water and foam concentrate from the tanks of the vehicle to be tested, three standard solutions shall be made up by pipe fitting, into three 3.381 fl oz (100 mL) graduated cylinders, volumes of foam concentrate in milliliters equal to the following:

- (1) The nominal concentration of the foam concentrate
- (2) One-third more than the nominal concentration of the foam concentrate
- (3) One-third less than the nominal concentration of the foam concentrate

6.2.2.2.2* The graduated cylinders shall then be filled to the 3.381 fl oz (100 mL) mark with water.

6.2.2.2.2.1 After thoroughly mixing, a refractive index or conductivity reading shall be taken of each standard solution.

6.2.2.2.2.2 A plot shall be made of the scale reading against the known foam solution concentrates and serve as a calibration curve for this particular series of foam tests.

6.2.2.3* Test Sample Concentration.

6.2.2.3.1 Portions of solution drained during the drainage test described in 6.3.2.2 shall be used as a source of test sample for the concentration determination.

6.2.2.3.2 Refractive index or conductivity readings of the test sample shall be compared to the calibration curve, and the corresponding foam solution concentration read from the graph.

6.2.3 Method B (Output-Based Testing Using a Refractometer Only). A calculation shall be made using the apparatus and procedure described in 6.2.3.1 and 6.2.3.2.

6.2.3.1* Apparatus. The concentration determination shall be made using the following apparatus:

- (1) Three clean plastic or glass containers
- (2) One dropper or pipette
- (3) A refractometer with a scale capable of reading the complete refractive index for the samples

6.2.3.2 Procedure. Using water and foam concentrate from the tanks of the vehicle to be tested, sample concentrations shall be determined as follows:

- (1) Obtain a foam concentrate sample in a clean container and label “foam concentrate.”
- (2) Obtain a water sample from the truck water tank or pump water discharge in a second clean container and label “water.”
- (3) Allow foam solution to discharge from a hoseline or turret for at least 30 seconds. Obtain a foam solution sample from the discharge device in a third clean container and label “foam solution.” The portions of drained solution obtained during the drainage test described in 6.3.3.2 can be used for the “foam solution” sample.
- (4) Take a refractive index reading for the water sample. Record the reading as R_w .
- (5) Clean the instrument.
- (6) Repeat step (4) with foam concentrate. Record the reading as R_c .
- (7) Clean the instrument.
- (8) Repeat step (4) with foam solution. Record the reading as R_s .

6.2.3.3 Test Sample Concentration. Determining the foam concentration of the foam solution sample shall be done by calculating the following formula using the readings obtained in the steps given in 6.2.3.1 (4), 6.2.3.1 (6), and 6.2.3.1 (8):

$$\% \text{ foam solution concentration} = \frac{R_s - R_w}{R_c - R_w} \times 100$$

6.2.4* Method C (Input-Based Testing). A determination of the flow rates shall be made possible using the procedure and apparatus in 6.2.4.1 through 6.2.4.3.

6.2.4.1 Apparatus. A device shall be used to measure the flow rate for the concentrate or the concentrate substitute.

6.2.4.1.1 A test sheet shall be compiled for each vehicle with measured water flow rates for each discharge, and the corresponding operational settings for the vehicle, as needed, in order to provide a known water flow rate from the water pump during each test.

6.2.4.1.2 A concentrate substitute shall be used instead of actual concentrate.

6.2.4.2 Procedure.

6.2.4.2.1 The foam concentration tank shall be closed off (or the tank shall be emptied and filled with substitute).

6.2.4.2.1.1 An alternative substitute shall flow in such a manner that the flow rates for the concentrate substitute can be read during testing.

6.2.4.2.2 Using the vehicle’s operational settings for producing foam, the operator shall test each discharge once flow rates have stabilized.

6.2.4.2.3 The flow rates for each discharge shall then be noted, together with any operational readings that could impact the water flow rates, such as water flow, concentrate flow, water pressure, or rpm.

6.2.4.2.4 After completing the testing, the concentrate supply pipes shall be drained for any concentrate substitute in order to prevent dilution of the concentrate in the concentrate tank.



6.2.4.3 Concentration. The foam solution concentrate shall be determined using this formula:

$$\frac{\text{Concentrate (or substitute)} \\ \text{flow rate or volume} \times 100}{\text{Concentrate flow rate or volume} + \\ \text{Water flow rate or volume}} = \% \text{ foam solution concentration}$$

6.3 Foam Expansion and Drainage Determination.

6.3.1 General Requirements.

6.3.1.1 Tests shall be conducted with the temperature of the water or foam solution in the range of 60°F to 80°F (16°C to 27°C).

6.3.1.2 The following corrections shall be applied to protective foams:

- (1) *Expansion ratio.* If the solution temperature is higher than 70°F (21°C), no correction shall apply. If the temperature is lower than 70°F (21°C), 0.1 unit of expansion shall be added for each 3°F (1.7°C) below 70°F (21°C).
- (2) *Drainage time.* If the solution temperature is higher than 70°F (21°C), 0.1 minute shall be added for each 3°F (1.7°C) above 70°F (21°C). If the solution temperature is lower than 70°F (21°C), 0.1 minute shall be subtracted for each 3°F (1.7°C) below 70°F (21°C).

6.3.1.3 Foam samples selected for analysis shall be representative of the foam produced by the nozzle as it would be applied to the fire hazard.

6.3.1.4 This selection shall be accomplished by placing a foam sample collector in the center of the ground pattern as determined in the nozzle pattern test.

6.3.1.5 Apparatus. The expansion and drainage determinations shall be made using the following apparatus, in addition to the specific apparatus required for Method A or Method B:

- (1) Stopwatch
- (2) Scale/balance
- (3) Straightedge

6.3.2 Test Method A.

6.3.2.1 Foam Sampling Apparatus.

6.3.2.1.1 The foam sample collector shall be constructed as specified in Figure 6.3.2.1.1.

6.3.2.1.2 The foam sample shall be collected in a standard 33.814 fl oz (1000 mL) capacity graduated cylinder.

6.3.2.1.2.1 The cylinder shall be cut off at the 33.814 fl oz (1000 mL) mark to ensure a fixed volume of foam as a sample.

6.3.2.1.2.2 The cylinder shall be marked in 0.338 fl oz (10 mL) graduations below the 3.381 fl oz (100 mL) mark.

6.3.2.2 Test Procedure.

6.3.2.2.1 The empty weight of the foam sample container shall be recorded to the nearest gram on a scale/balance having a maximum capacity sufficient to weigh the foam sample container and the foam sample.

6.3.2.2.1.1 The foam sample collector shall then be located in the center of the discharge pattern determined in Section 6.5.

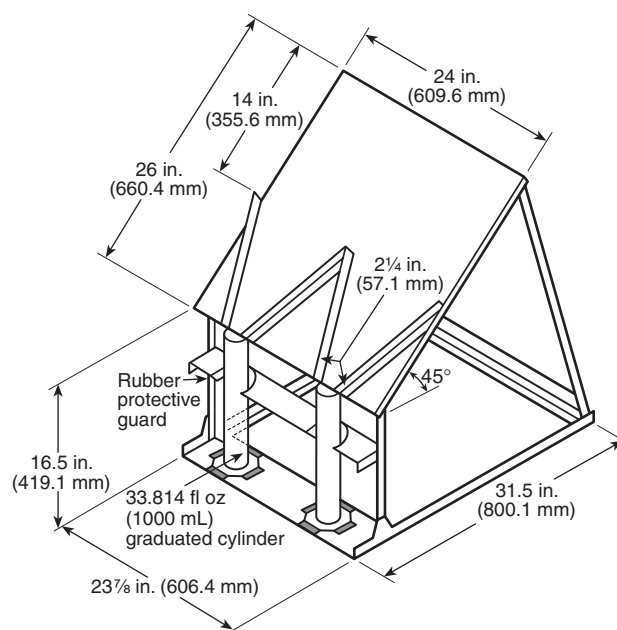


FIGURE 6.3.2.1.1 Foam Sample Collector, Method A.

6.3.2.2.1.2 The foam sample container shall be positioned at the bottom of the foam collector so that the foam hitting the collector flows into the container.

6.3.2.2.1.3 The foam nozzle shall be aimed so that the foam deflects off the side of the foam collector, adjusted to its normal operating pressure, and then moved so as to discharge foam onto the foam sample collector.

6.3.2.2.1.4 As soon as the foam sample container has been completely filled with foam, the discharge nozzle shall be shut off and the timing of the 25 percent drainage started.

6.3.2.2.2 The foam sample container shall be removed from the base of the foam collector, excess foam struck off the top of the foam container using a straightedge, and any remaining foam wiped from the outside surface of the container.

6.3.2.2.3* The container shall then be placed on a level surface at a convenient height.

6.3.2.2.3.1 At 30-second intervals, the level of accumulated solution in the bottom of the cylinder shall be noted and recorded.

6.3.2.2.3.2 The drainage shall be recorded until the liquid level reaches 3.212 fl oz (95 mL) for non-aspirated nozzles, 2.029 fl oz (60 mL) for air-aspirated nozzles.

6.3.2.2.4 The container shall then be placed on the scale/balance.

6.3.2.2.4.1 The total weight of the foam sample and container shall be determined to the nearest gram.

6.3.2.2.4.2 The weight of the foam sample in the container shall be determined by subtracting the weight of the empty container from the weight of the container filled with the foam.

6.3.2.2.4.3 The weight of the foam sample in grams shall be divided by 4 to obtain the equivalent 25 percent drainage volume in fluid ounces (milliliters).

6.3.2.2.4.4 The 25 percent drainage time shall then be interpolated from the drainage data collected in 6.3.2.2.3.1 and 6.3.2.2.3.2.

6.3.2.2.5 Samples of the foam shall be weighed to the nearest gram. The expansion of the foam shall be calculated by the following equation:

$$\text{Expansion} = \frac{33.814 \text{ fl oz (1000 mL)}}{(\text{full weight}) - (\text{empty weight in grams})}$$

6.3.3 Test Method B.

6.3.3.1 Foam Sampling Apparatus.

6.3.3.1.1 The object shall be to obtain a sample of foam that is typical of that to be applied to the burning fuel surface under anticipated fire conditions.

6.3.3.1.1.1 The foam collector shall be constructed as specified in Figure 6.3.3.1.1.1.

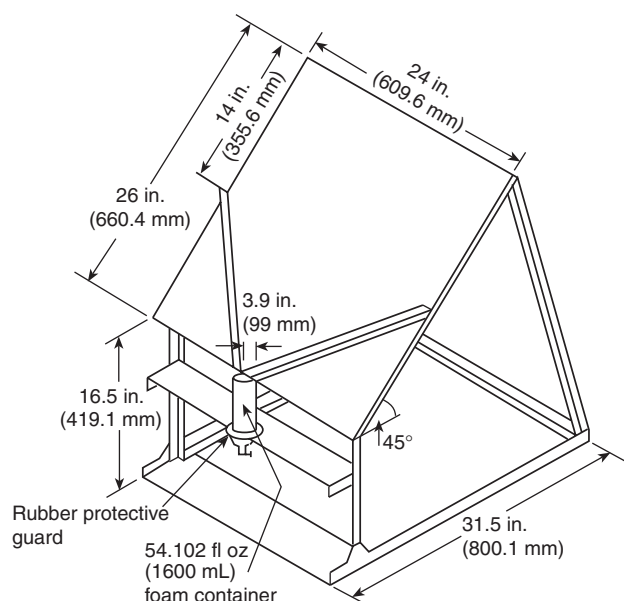


FIGURE 6.3.3.1.1.1 Foam Sample Collector, Method B.

6.3.3.1.2 The foam sample shall be collected in a cylindrical 54.102 fl oz (1600 mL) container.

6.3.3.1.2.1 The foam sample container shall be constructed as specified in Figure 6.3.3.1.2.1.

6.3.3.1.3 Foam drainage shall be recorded using a 3.381 fl oz (100 mL) graduated beaker for foams with expected expansion ratios above 5:1, and a 8.454 fl oz (250 mL) graduated cylinder for foams with expected expansion ratios of 5:1 or below.

6.3.3.1.4 The weight of the appropriate empty graduated cylinder shall be recorded before the test.

6.3.3.2 Test Procedure.

6.3.3.2.1 The empty weight of the foam sample container shall be recorded to the nearest gram on a scale/balance having a maximum capacity sufficient to weigh the foam sample container, on a suitable support, and the foam sample.

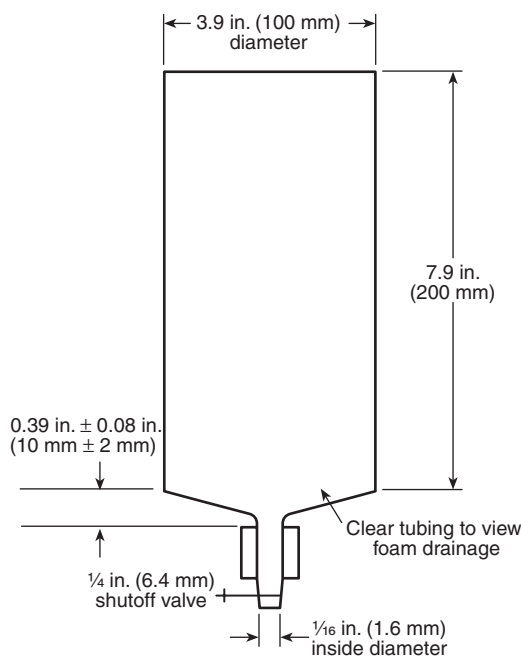


FIGURE 6.3.3.1.2.1 54.102 fl oz (1600 mL) Foam Sample Container.

6.3.3.2.1.1 The foam sample collector shall then be located in the center of the discharge pattern determined in Section 6.5 of this standard.

6.3.3.2.1.2 The foam sample container shall be positioned at the bottom of the foam collector so that the foam hitting the collector will flow into the container.

6.3.3.2.1.3 The foam nozzle shall be aimed so that the foam deflects off the side of the foam collector, adjusted to its normal operating pressure, and then moved so as to discharge foam onto the foam sample collector.

6.3.3.2.1.4 As soon as the foam sample container has been completely filled with foam, the discharge nozzle shall be shut off and the timing of the 25 percent drainage started.

6.3.3.2.2 The foam sample container shall be removed from the base of the foam collector, excess foam struck off the top of the foam container using a straightedge, and any remaining foam wiped from the outside surface of the container.

6.3.3.2.2.1 The container shall then be placed on the scale/balance.

6.3.3.2.2.2 The total weight of the foam sample and container shall be determined to the nearest gram.

6.3.3.2.2.3 The weight of the foam sample in the container shall be determined by subtracting the weight of the empty container from the weight of the container filled with the foam.

6.3.3.2.2.4 The weight of the foam sample in grams shall be divided by 4 to obtain the equivalent 25 percent drainage volume in milliliters.

6.3.3.2.3 The foam sample container shall then be placed on a suitable support and a graduated cylinder placed below the drain spout.

6.3.3.2.3.1 At 30-second intervals, the accumulated solution in the bottom of the foam sample container shall be drawn off into the graduated cylinder and the amount recorded.

6.3.3.2.3.2 The drainage shall be recorded until the liquid level reaches 5.072 fl oz (150 mL) for non-aspirated nozzles, 3.212 fl oz (95 mL) for air-aspirated nozzles.

6.3.3.2.4 The foam sample container complete with any remaining foam shall then be weighed to the nearest gram.

6.3.3.2.4.1 The graduated cylinder used to record the drainage and the collected foam shall then be weighed in the same manner.

6.3.3.2.4.2 The net weight of the foam sample shall be determined by adding the weights in 6.3.3.2.4 and 6.3.3.2.4.1 together and subtracting the weight of the empty foam sample container and the empty graduated cylinder.

6.3.3.2.4.3 The net weight of the foam sample in grams shall be divided by 4 to obtain the equivalent 25 percent drainage volume in milliliters.

6.3.3.2.5* The expansion of the foam shall be calculated by the following equation:

$$\text{Expansion} = \frac{54.102 \text{ fl oz (1600 mL)}}{\text{net weight of foam sample in grams}}$$

6.4 Ground Sweep Nozzle and Hand Line Nozzle Tests.

6.4.1 Ground sweep nozzles and hand line foam nozzles shall be discharged onto a paved surface for a period of 30 seconds.

6.4.2 Ground sweep nozzles shall be discharged from their fixed positions.

6.4.3 Hand line nozzles shall be held at their normal working height and tilted upward to form a 30-degree angle with the horizontal.

6.4.4 Markers shall be set out to denote the outline of the effective foam pattern and plotted, as described for the turret test in 6.5.3.

6.4.5 Patterns from both the straight stream and the fully dispersed nozzle settings shall be established, measured, and recorded.

6.5 Turret Ground Pattern Test.

6.5.1 Prior to the start of the test, the water tank shall be full, the foam concentrate tank shall be full with the type of foam concentrate to be used during actual emergencies, and the proportioner shall be set for normal fire-fighting operation.

6.5.1.1 For premixed systems, the tank shall be full with the premixed solution in the correct proportion for normal fire-fighting operations.

6.5.2* Discharge tests shall be conducted to establish the fire-fighting foam discharge patterns produced and the maximum range attainable by the turret nozzle.

6.5.2.1 The test shall be conducted under wind conditions of 5 mph (8 km/h) or less.

6.5.2.2 To determine maximum discharge range, the turret nozzles shall be tilted upward to form a 30-degree angle with the horizontal.

6.5.3 Foam shall be discharged onto a paved surface for a period of 30 seconds at the specified pressure, in both the straight stream and fully dispersed nozzle settings.

6.5.3.1 Immediately after foam discharge has stopped, markers shall be placed around the outside perimeter to preserve the identity of the foam pattern as it fell on the ground.

6.5.3.2 For purposes of defining the edge of the pattern, any foam less than ½ in. (12.7 mm) in depth shall be disregarded.

6.5.3.3 Distances between markers shall be plotted on graph paper.

6.5.3.4 The vertical axis shall show the reach, and the horizontal axis shall show the pattern width, for each nozzle setting.

6.5.3.5 The distance from the nozzle to the end of the effective foam pattern shall be measured and plotted on the graph paper.

6.6 Report of Test Results.

6.6.1* All test reports shall include a statement of the operating conditions, such as pressures, temperatures, wind velocities, and direction in relation to vehicle position, and a full description of the materials and equipment used.

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.3.3.1 Foam. Air foam is made by mixing air into a water solution containing a foam concentrate by means of suitably designed equipment. It flows freely over a burning liquid surface and forms a tough, air-excluding, continuous blanket that seals volatile combustible vapors from access to air. It resists disruption from wind and draft or heat and flame attack and is capable of resealing in case of mechanical rupture. Fire-fighting foams retain these properties for relatively long periods of time.

A.3.3.1.1 Alcohol-Resistant Foam Concentrate. Some alcohol-resistant foams might be capable of forming a vapor-suppressing aqueous film on the surface of hydrocarbon fuels.

A.3.3.1.2 Aqueous Film-Forming Foam (AFFF) Concentrate. The foam produced from AFFF concentrates is dry-chemical compatible and is, therefore, suitable for use in combination with that agent.

A.3.3.1.3 Film-Forming Fluoroprotein (FFFP) Foam Concentrate. This foam might show an acceptable level of compatibility with dry chemicals and might be suitable for use with those agents.

A.3.3.2 Foam Concentrate. For the purpose of this document, “foam concentrate” and “concentrate” are used interchangeably. [11, 2010]

A.5.2.1 The amount of foam concentrate in the solution fed to the foam maker plays an important part, not only in the making of foam with the proper expansion and drainage rate, but also in making a fire-resistant foam. Therefore, it is essential that correct proportioning is maintained and that the concentration meets the required level, even if the foam meets

the minimum expansion and drainage time values at other levels of concentration.

A.6.1(4) To ensure that the foam concentrate from vehicle tank(s) has not been contaminated, a foam concentrate sample from the foam tank(s) should be compared to a new virgin sample of the same type and brand.

Any significant difference indicates possible water contamination of the foam concentrate in the vehicle. The methods used for concentrate comparison should be as described in Section 6.2.

A.6.2.1 The conductivity method is not recommended where seawater is used for making foam solution.

When the conductivity method is used and samples are to be stored and analyzed at some time other than during testing, clean glass containers should be used to store the samples.

Storage of solution in other types of containers (metal, low-density polyethylene) might affect the conductivity reading over a period of time. Care should be taken that conductivity measurements are made when the water and foam solution are at the same temperature. Small differences in temperature might substantially change conductivity measurements.

The recommended meter automatically compensates for different temperatures. If other meters are used, the instructions for the conductivity meter calibration and temperature compensation should be carefully followed.

A.6.2.2 See Figure A.6.2.2(a), Figure A.6.2.2(b), and Figure A.6.2.2(c).

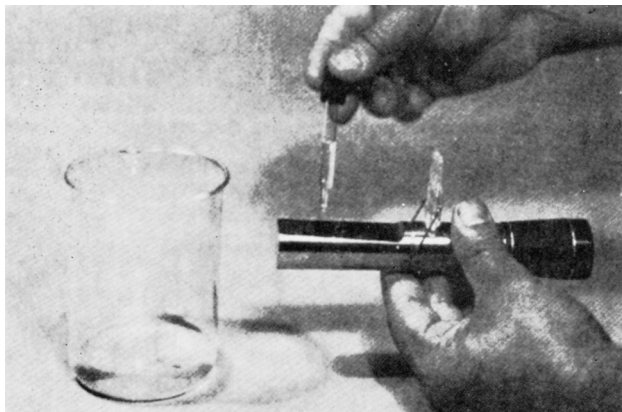


FIGURE A.6.2.2(a) Measuring the Index of Refraction by Placing a Few Drops of the Solution to Be Tested on the Prism of a Refractometer and Closing the Cover Plate. This is a typical refractometer suitable for this purpose.

A.6.2.2.2.2 Method A procedures are used to provide a reference line on which the reading of the solution tested is plotted to determine its exact concentration. Figure A.6.2.2.2.2(a) shows a typical graph using 6 percent AFFF solution, and Figure A.6.2.2.2.2(b) shows a typical graph using a 6 percent FFFP solution.

A.6.2.2.3 Because of the high sensitivity of the conductivity meter, it is necessary to collect a larger sample of drainage before making the determination. This will allow for the variation in conductivity of the drained liquid caused by small changes in the chemical composition of AFFF solution as it drains over a period of time.



FIGURE A.6.2.2(b) Holding this Type of Refractometer Up to a Light Source to Take a Reading Where the Dark Field Intersects the Numbered Scale.

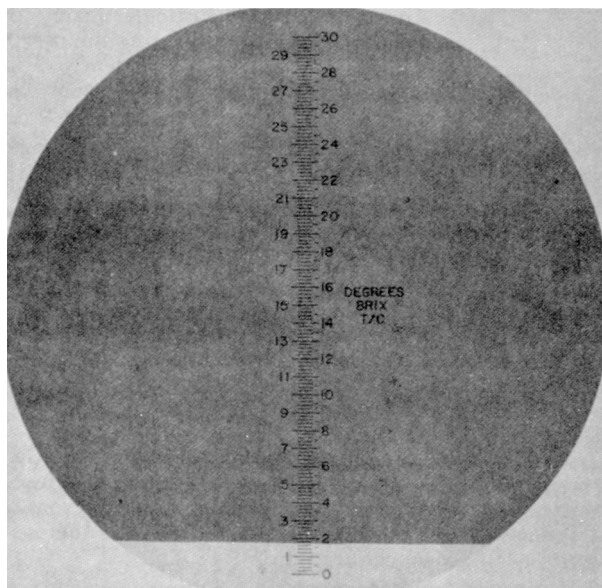


FIGURE A.6.2.2(c) Illustrating the Field of View by Looking into the Refractometer Shown in Figures A.6.2.2(a) and A.6.2.2(b) Containing a 6 Percent AFFF Solution. The dark intersects the scale at 1.7, and this value is recorded as the reading for a 6 percent concentration.

The equipment used to determine concentration should enable the user to accurately measure whether the foam solution produced by proportioning equipment is within the tolerance specified in 5.2.1 and 5.2.2. Conductivity meters should have an automatic temperature compensation feature and should measure a conductivity range of 0–199.9 $\mu\text{S}/\text{cm}$ in a low scale, and 0–199.9 mS/cm in a high scale.

A.6.2.3.1 However, low-range refractometers (e.g., 0–10 Brix) might not be able to provide a 100 percent concentration reading of the foam concentrate when using Method B. This is particularly true when using 1 percent and 3 percent foam concentrates.

A.6.2.4 Test Method C should not be used as an acceptance test.

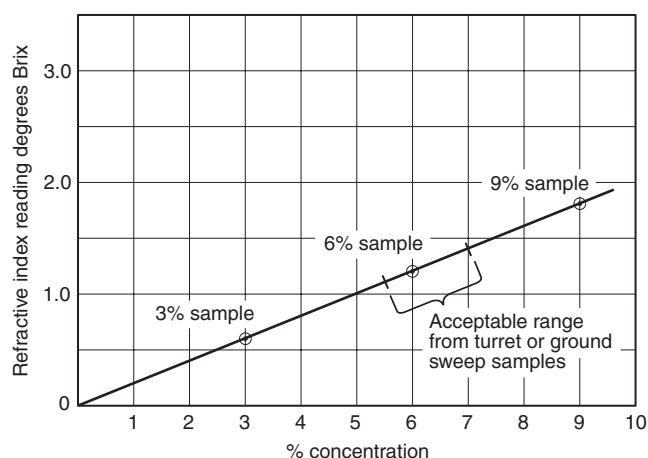


FIGURE A.6.2.2.2(a) Typical Graph Using AFFF (6%).

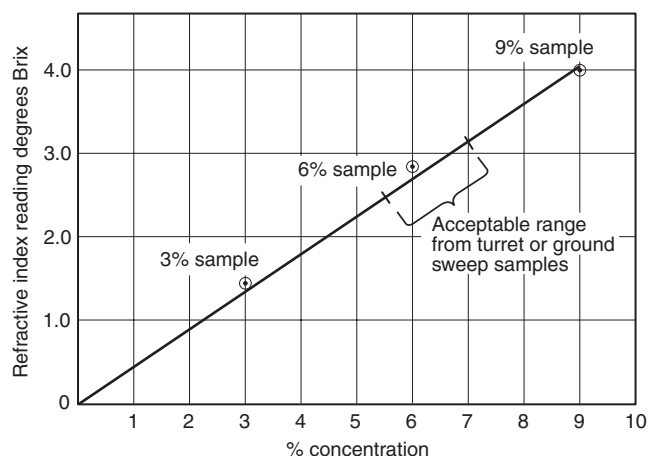


FIGURE A.6.2.2.2(b) Typical Graph Using FFFP (6%).

A.6.3.2.2.3 The following equation is an example calculation of drainage time. The net weight of the foam sample in the foam container is assumed to be 200 g. Since 1 g of foam solution occupies approximately 0.034 fl oz (1 mL), the total volume of foam solution contained in the given foam sample is 6.763 fl oz (200 mL):

$$25\% \text{ drainage volume} = \frac{\text{volume of solution}}{4} = \frac{200 \text{ mL}}{4} = 50 \text{ mL}$$

The time versus solution volume data are recorded as shown in Table A.6.3.2.2.3.

It is seen that the 25 percent volume of 1.691 fl oz (50 mL) lies within the 2- to 3-minute period. The increment to be added to the lower value of 2 minutes is found by interpolation of the data:

$$\frac{50 \text{ mL}(25\% \text{ volume}) - 40 \text{ mL}(2\text{-min volume})}{60 \text{ mL}(3\text{-min volume}) - 40 \text{ mL}(2\text{-min volume})} = \frac{10}{20} = 0.5$$

Therefore, the 25 percent drainage time is found by adding 0.5 minute to 2.0 minutes, giving a final value of 2.5 minutes, or 2 minutes 30 seconds.

Table A.6.3.2.2.3 Drainage Time

| Time (min:sec) | Assumed Drained Solution Volume | |
|-------------------|------------------------------------|----|
| | fl oz | mL |
| 0:00 | 0 | 0 |
| 0:30 | 0.338 | 10 |
| 1:00 | 0.676 | 20 |
| 1:30 | 1.014 | 30 |
| 2:00 | 1.353 | 40 |
| 2:30 | 1.691 | 50 |
| 3:00 | 2.029 | 60 |

A.6.3.3.2.5 The following equation shows the calculation of expansion. The net weight of the foam sample (see Table 5.1) is assumed to be 200 g; therefore, the volume of foam solution contained in the 54.102 fl oz (1600 mL) foam sample is 6.763 fl oz (200 mL).

$$\text{Expansion} = \frac{\text{volume of foam}}{\text{volume of solution}} = \frac{1600}{200} = 8$$

A.6.5.2 See Figure A.6.5.2.

A.6.6.1 Figure A.6.6.1(a) and Figure A.6.6.1(b) show forms for use in reporting and graphing test results.

Annex B Foam Extinguishing System Capability

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 Foam Extinguishing System Capability.

B.1.1 Basic Extinguishing Capability. The following is a suggested method for evaluating the basic extinguishing capability of the foam fire-fighting system. This method can be used to determine fire-fighting capability of systems that do not meet the requirements listed in NFPA 414.

B.1.1.1 Foam performance is judged on two criteria: (1) ability for quick knockdown of flames, and (2) ability to keep the fuel area secure against re-ignition. High application rates will overwhelm the fire and obscure any possible shortcomings. Fire tests sufficiently large to challenge the foam equipment are very costly and difficult to conduct without creating undue environmental problems. Therefore, an attempt is made in this standard to devise a restricted but still significant procedure. To obtain meaningful information, it is necessary that the foam be applied at low rates per square foot of fuel surface. This will represent the performance to be expected when the system is pushed to its ultimate capability on a large fire.

B.1.1.2 A foam vehicle user might utilize the basic test procedure in several ways. For example, it might be desired to establish the minimum rate of foam application at which a fire can be extinguished. By using this rate and the time for extinguishment, the volume of water required to extinguish one unit of fire area (square foot or square meter), and the maximum fire area the vehicle is capable of extinguishing, can be calculated. It should be kept in mind, however, that the most efficient use of water contributes to long extinguishing times. In practice, a high application rate is required because it gives

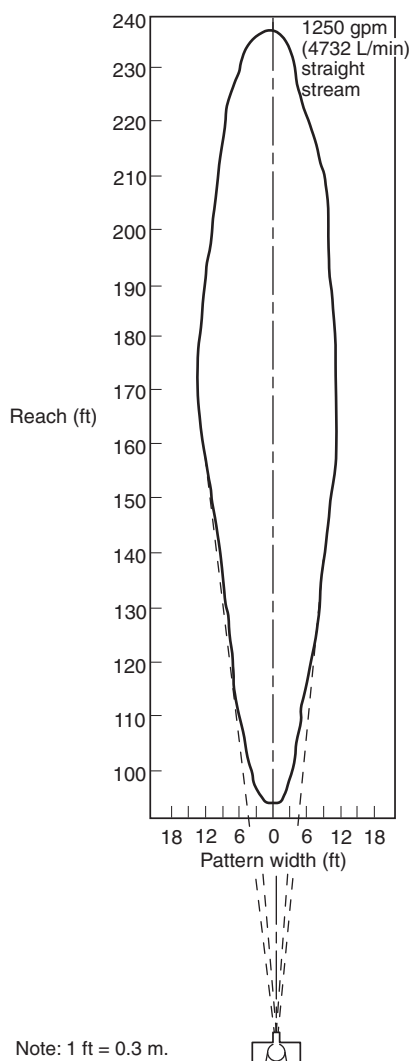


FIGURE A.6.5.2 Typical Foam Discharge Pattern.

the most rapid knockdown of flame, although it will be less efficient in terms of agent consumed. Operation of the turret to achieve complete extinguishment also wastes water. Generally, after the fire has been 90 percent extinguished, it is better to shut down the turret and complete the extinguishment by application of foam from hand lines or by the application of one of the complementary agents.

B.1.1.3 A user might desire to compare the system used on two different fuels or under several different weather conditions, such as high winds, heavy rain, or extreme low temperatures, or with obstacles within the fire area. In this type of testing, care should be taken to change only one variable at a time. All other conditions should remain the same.

B.1.1.4 A user might desire to check the foam used against its “as purchased” condition. Here the tests should be conducted under the same conditions as those prevailing during the original tests.

B.1.2 Turret or Hand Line Extinguishing Tests.

FOAM PHYSICAL PROPERTY TESTS WORKSHEET (In accordance with NFPA 412)

DATE:
TEST NO:
LOCATION:
TEST SUBJECT:

VEHICLE:
TYPE FOAM LIQUID CONCENTRATE:

FOAM MAKER: PATTERN SETTING:

OPERATING PRESSURE: psi AT PUMP, NOZZLE

FLOW: gpm

AIR TEMP:°F WATER TEMP:°F

WIND:mph DIRECTION RELATIVE TO PATTERN AXIS:

Gross weight of full foam container* grams

Weight of empty container grams

Net weight of foam sample grams

*Foam container must have the dimensions as specified in NFPA 412.

$$\text{Foam expansion} = \frac{\text{Volume of foam container}}{\text{Net weight of foam sample}} = \frac{\text{..... mL}}{\text{..... grams (from above)}} = \text{.....}$$

$$\begin{aligned} 25\% \text{ volume} &= \frac{\text{Net weight of foam sample}}{4} \\ &= \frac{\text{..... grams (from above)}}{4} = \text{..... mL} \end{aligned}$$

FIGURE A.6.6.1(a) Worksheet for Reporting Results of Foam Physical Properties Test.

B.1.2.1 The exact size of the fire to be used is not critical; however, it should not be less than 100 ft² (10 ft × 10 ft) [9 m² (3 m × 3 m)] in area. Large-scale testing has shown that larger — 11,580 ft² (107.8 ft × 107.8 ft) [1075.8 m² (32.8 m × 32.8 m)] — fire areas do not necessarily require higher application rates or greater quantities of agent (foam) per unit area.

B.1.2.2 The choice of fuel depends on the data desired. Gasolines are normally the most difficult fuels to extinguish, a Jet A (JP-5) the easiest. Jet B (JP-4) is a variable fuel without a definitive flash point.

B.1.2.3 Water can be used to level a large pit to ensure a level fuel area, and bare ground should be presoaked to prevent the loss of fuel. The amount of fuel to be used is partially dependent on the length of preburn to be allowed. With preburn times of 1 minute, at least 1 gal (3.8 L) of fuel for each 2 ft² (0.2 m²) of area should be used.

B.1.2.4 Local clean air regulations might dictate the length of preburn, since this is the period of greatest smoke generation.

B.1.2.5 Establishing and maintaining the desired rate of foam application will require some work and practice prior to

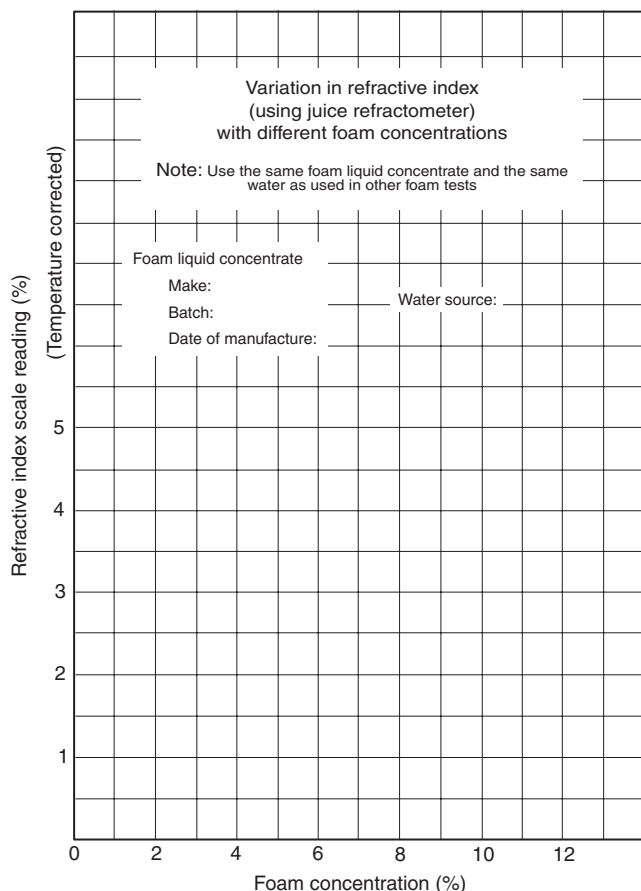


FIGURE A.6.6.1(b) Worksheet for Graphing Results of Foam Physical Properties Test.

conducting the fire test. The objective is to sweep the turret or nozzle discharge back and forth over the fire area at an even rate in order to apply the foam at the desired rate [gpm/ft² (Lpm/m²)].

B.1.2.6 The actual rate is checked by placing 1 ft² (0.1 m²) (or other known convenient size of known area) shallow pans near the edges of the fire area. After the foam discharge pattern has been swept back and forth over the fire area and pans for a measured period of time, the stream is shut off, the weight of the contents of each pan determined, and the application rate calculated. If the rate was too high, a faster rate and wider angle of sweep will be required and vice versa. Once the proper technique has been worked out, the fire is extinguished in the same manner. The pans can be used during the fire test to verify the application rate. NFPA 403 requires a rate of 0.13 gpm/ft² (5.3 Lpm/m²) for AFFF, 0.20 gpm/ft² (8.1 Lpm/m²) for protein foam, and 0.18 gpm/ft² (7.3 Lpm/m²) for fluoroprotein foam.

B.1.2.7 The following calculations are typical of those used in the determination of the basic extinguishing capability of an aircraft rescue and fire-fighting vehicle of 1000 gal (3785 L) water capacity:

| | |
|---|--------|
| Gross weight of pan with collected foam | 412 oz |
| Empty weight of pan | 350 oz |
| Net weight of foam sample | 62 oz |

$$\text{Water collected} = \frac{\text{foam wt, oz}}{133.3} = \frac{62}{133.3} = 0.465 \text{ gal}$$

$$\text{Total water applied} = \frac{\text{water collected, gal}}{\text{area of pan, ft}^2} = \frac{0.465}{3.5} = 0.133 \text{ gal/ft}^2$$

$$\text{Basic extinguishing capability} = \frac{1000 \text{ gal}}{0.133 \text{ gal/ft}^2} = 7600 \text{ ft}^2/1000 \text{ gal}$$

B.1.3 Burnback Test.

B.1.3.1 The resistance of the foam blanket to the fire is important. Wind plays a big role in the determination of this property and repeat results are difficult to obtain with an outdoor test. Another factor, but one easier to control, is the size of the fire area at the start of re-ignition. Burnback performance requirements can be referenced using Underwriters Laboratories Inc. Standard UL 162, *Standard for Foam Equipment and Liquid Concentrates*, or U.S. Military Specification MIL-F-24385, *Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF), Liquid Concentrate for Fresh and Sea Water*.

B.1.3.2 Burnback resistance is related to the amount of foam that has been applied to the fire. A burnback test on a fire area that has been extinguished with a minimum application of foam will not afford a high level of protection.

B.1.3.3 To compare the degree of burnback protection of different agents and depths of foam, and to familiarize the crew with the degree of protection afforded, repeated tests using varied delays between end of foam application and start of re-ignition are suggested.

Annex C Informational References

C.1 Referenced Publications. The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

C.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 403, *Standard for Aircraft Rescue and Fire-Fighting Services at Airports*, 2014 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire-Fighting Vehicles*, 2012 edition.

C.1.2 Other Publications. Standard UL 162, *Standard for Foam Equipment and Liquid Concentrates*, 1994, Revised 1999.

U.S. Military Specification MIL-F-24385, *Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF), Liquid Concentrate for Fresh and Sea Water*, August 5, 1994.

C.2 Informational References. (Reserved)

C.3 References for Extracts in Informational Sections.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2010 edition.

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Sequence of Events Leading to Issuance of This NFPA Committee Document

Step 1: Call for Proposals

- Proposed new Document or new edition of an existing Document is entered into one of two yearly revision cycles, and a Call for Proposals is published.

Step 2: Report on Proposals (ROP)

- Committee meets to act on Proposals, to develop its own Proposals, and to prepare its Report.
- Committee votes by written ballot on Proposals. If two-thirds approve, Report goes forward. Lacking two-thirds approval, Report returns to Committee.
- Report on Proposals (ROP) is published for public review and comment.

Step 3: Report on Comments (ROC)

- Committee meets to act on Public Comments to develop its own Comments, and to prepare its report.
- Committee votes by written ballot on Comments. If two-thirds approve, Report goes forward. Lacking two-thirds approval, Report returns to Committee.
- Report on Comments (ROC) is published for public review.

Step 4: Technical Report Session

- “*Notices of intent to make a motion*” are filed, are reviewed, and valid motions are certified for presentation at the Technical Report Session. (“Consent Documents” that have no certified motions bypass the Technical Report Session and proceed to the Standards Council for issuance.)
- NFPA membership meets each June at the Annual Meeting Technical Report Session and acts on Technical Committee Reports (ROP and ROC) for Documents with “certified amending motions.”
- Committee(s) vote on any amendments to Report approved at NFPA Annual Membership Meeting.

Step 5: Standards Council Issuance

- Notification of intent to file an appeal to the Standards Council on Association action must be filed within 20 days of the NFPA Annual Membership Meeting.
- Standards Council decides, based on all evidence, whether or not to issue Document or to take other action, including hearing any appeals.

Committee Membership Classifications

The following classifications apply to Technical Committee members and represent their principal interest in the activity of the committee.

- M *Manufacturer*: A representative of a maker or marketer of a product, assembly, or system, or portion thereof, that is affected by the standard.
- U *User*: A representative of an entity that is subject to the provisions of the standard or that voluntarily uses the standard.
- I/M *Installer/Maintainer*: A representative of an entity that is in the business of installing or maintaining a product, assembly, or system affected by the standard.
- L *Labor*: A labor representative or employee concerned with safety in the workplace.
- R/T *Applied Research/Testing Laboratory*: A representative of an independent testing laboratory or independent applied research organization that promulgates and/or enforces standards.
- E *Enforcing Authority*: A representative of an agency or an organization that promulgates and/or enforces standards.
- I *Insurance*: A representative of an insurance company, broker, agent, bureau, or inspection agency.
- C *Consumer*: A person who is, or represents, the ultimate purchaser of a product, system, or service affected by the standard, but who is not included in the *User* classification.
- SE *Special Expert*: A person not representing any of the previous classifications, but who has a special expertise in the scope of the standard or portion thereof.

NOTES:

1. “Standard” connotes code, standard, recommended practice, or guide.
2. A representative includes an employee.
3. While these classifications will be used by the Standards Council to achieve a balance for Technical Committees, the Standards Council may determine that new classifications of members or unique interests need representation in order to foster the best possible committee deliberations on any project. In this connection, the Standards Council may make appointments as it deems appropriate in the public interest, such as the classification of “Utilities” in the National Electrical Code Committee.
4. Representatives of subsidiaries of any group are generally considered to have the same classification as the parent organization.