NFPA®

412

Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment

2020

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NFPA® 412

Standard for

Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment

2020 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 April 28, 2019, with an effective date of May 18, 2019, and supersedes all previous editions.

This edition of NFPA 412 was approved as an American National Standard on May 18, 2019.

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 revised many of the requirements regarding foam and the testing and test method requirements for foam. These updated requirements allowed a broader use and application of foams along with the methods and equipment that were 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.

The 2020 edition makes minor changes from the previous edition. The technical committee has added fluorine-free foam to the list of agents, as well as a new requirement to check the vehicle's foam tank for crystallization of foam concentrate. Annex material has been added to clarify procedures for input-based foam testing. Minor editorial changes and updates to referenced documents have also been made.

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Committee Scope: This Committee shall have primary responsibility for aircraft rescue and fire-fighting (ARFF) documents used by organizations providing ARFF services for operational procedures; training; foam testing and application; specialized equipment; and planning for aircraft emergencies.

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NFPA 412

Standard for

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

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

Information on referenced and extracted publications can be found in Chapter 2 and Annex 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,* 2018 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire-Fighting Vehicles,* 2020 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,* 2016 edition.

NFPA 403, *Standard for Aircraft Rescue and Fire-Fighting Services at Airports,* 2018 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.

N **3.2.1* 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.

3.2.2 Shall. Indicates a mandatory requirement.

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

3.2.4 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.

Δ **3.3.1* Foam.** An aggregation of small bubbles used to form an air-excluding, vapor-suppressing blanket over the surface of a flammable liquid fuel. [**403,** 2018]

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,** 2016]

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,** 2016]

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,** 2016]

N **3.3.1.4** ***Fluorine-Free Synthetic Foam.*** A synthetic foam concentrate containing no fluorochemicals for suppressing hydrocarbon fuel vapors.

3.3.1.5 ***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.

3.3.1.6 ***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,** 2016]

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.

Δ **Table 5.1 Foam Quality Requirements**

Foam Agents	Minimum Expansion Ratio	Minimum Solution 25% Drainage Time (min) Test Method A	Test Method B
AFFF/FFFP/Fluorine-Free air-aspirated	5:1	3	2.25
AFFF/FFFP/Fluorine-Free 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

Δ **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)* The foam tank of each vehicle shall be inspected for the presence of crystallization, gelling, or sediment.
(5)* For output-based testing, a sample of foam concentrate from the vehicle concentrate tank shall be obtained to form the baseline for concentration analysis and to determine whether the agent concentrate in the vehicle has been contaminated.
(6) The foam concentrate sample shall be compared with a sample of the same concentrate from the vehicle being tested.

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.

Δ **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 6.2.3.2(4) with foam concentrate. Record the reading as R_c.
(7) Clean the instrument.
(8) Repeat step 6.2.3.2(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 6.2.3.2(4), 6.2.3.2(6), and 6.2.3.2(8):

N **[6.2.3.3]**

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

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:

N **[6.2.4.3]**

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

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.

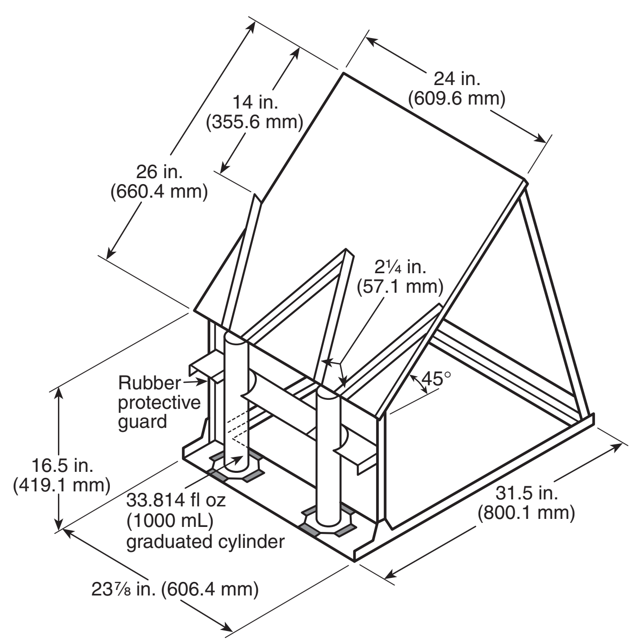

FIGURE 6.3.2.1.1 Foam Sample Collector, Method A.

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:

N **[6.3.2.2.5]**

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

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.

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

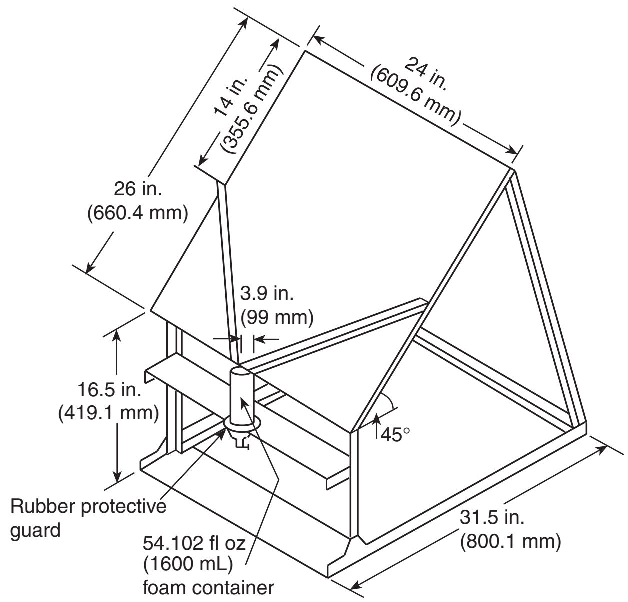

FIGURE 6.3.3.1.1.1 Foam Sample Collector, Method B.

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.

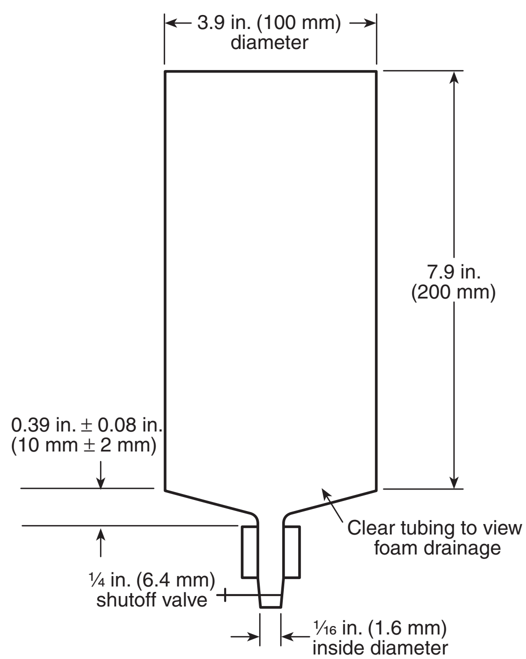

FIGURE 6.3.3.1.2.1 54.102 fl oz (1600 mL) Foam Sample Container.

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.

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:

N **[6.3.3.2.5]**

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

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.

N **A.3.2.1 Authority Having Jurisdiction (AHJ).** The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the AHJ may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the AHJ. In many circumstances, the property owner or his or her designated agent assumes the role of the AHJ; at government installations, the commanding officer or departmental official may be the AHJ.

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. Firefighting 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,** 2016]

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.

N **A.6.1(4)** The presence of contaminants inside a vehicle's foam tank could affect the performance of a vehicle's foam proportioner system. If crystallization, gelling, or sediment are found, it is recommended to remove the contaminants in accordance with guidance provided by the foam concentrate manufacturer prior to conducting testing. See FAA CertAlert 16-09, *Particles in Aqueous Film Forming Foam (AFFF) Tanks on Aircraft Rescue Fire Fighting (ARFF) Vehicles and AFFF Storage Tanks*, for additional information.

Δ **A.6.1(5)** 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 sample of the same type and brand.

If different foam concentrate products or concentrates from different manufacturers are mixed, they might stratify inside the vehicle's foam tank.

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.

Δ **A.6.2.2** A refractometer is used to measure the refractive index of the foam solution samples. This method is not particularly accurate for AFFF or alcohol-resistant AFFF because they typically exhibit very low refractive index readings. Therefore, the conductivity method might be preferred where those products are used. See Figure A.6.2.2(a), Figure A.6.2.2(b), Figure A.6.2.2(c), and Figure A.6.2.2(d).

Figure A.6.2.2(a) gives an example of a visual refractometer. The index of refraction is measured by placing a few drops of the solution to be tested on the prism of a refractometer, closing the cover plate, and 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(b) shows the view through the eyepiece of a visual refractometer, measuring a 6 percent AFFF solution. The dark section intersects the scale at 1.7, and this value is recorded as the reading for a 6 percent concentration.

Figure A.6.2.2(c) is an example of a digital refractometer. The index of refraction is measured by placing a few drops of the solution to be tested in the prism, following the user instructions of the device for calibration and cleaning requirements.

Figure A.6.2.2(d) is one style of conductivity meter. This device can be used to measure the electrical conductivity of a solution. These devices are typically easy to use and have repeatable results, by following the user instructions of the device for calibration and cleaning requirements.

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.

Δ **FIGURE A.6.2.2(a) Visual Refractometer.**

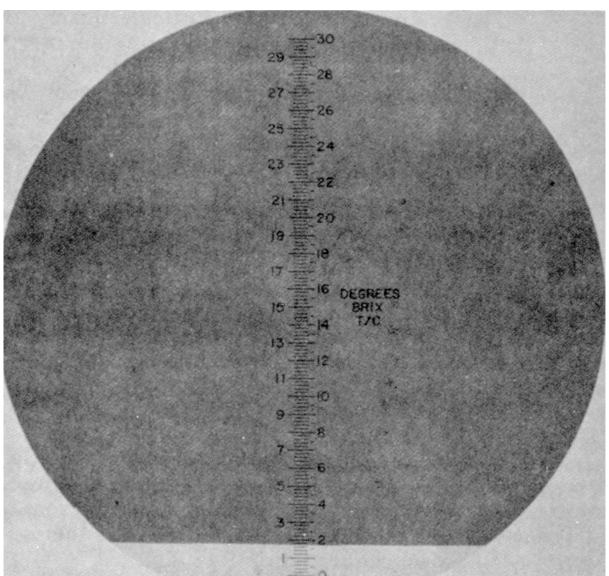

FIGURE A.6.2.2(b) Illustrating the Field of View by Looking into the Refractometer.

N **FIGURE A.6.2.2(c) Digital Refractometer.**

N **FIGURE A.6.2.2(d) Conductivity Meter.**

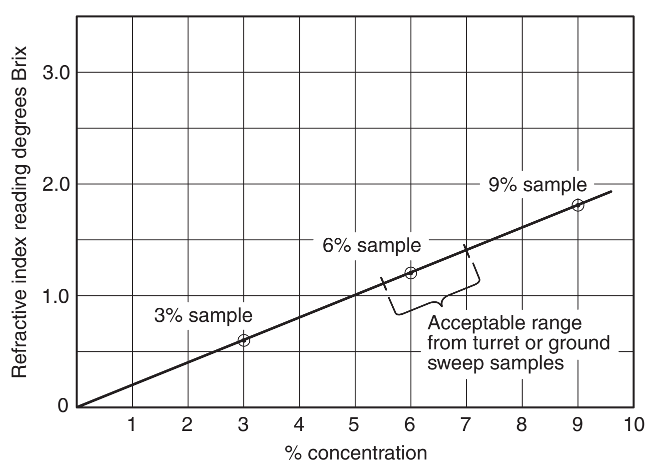

FIGURE A.6.2.2.2.2(a) Typical Graph Using AFFF (6%).

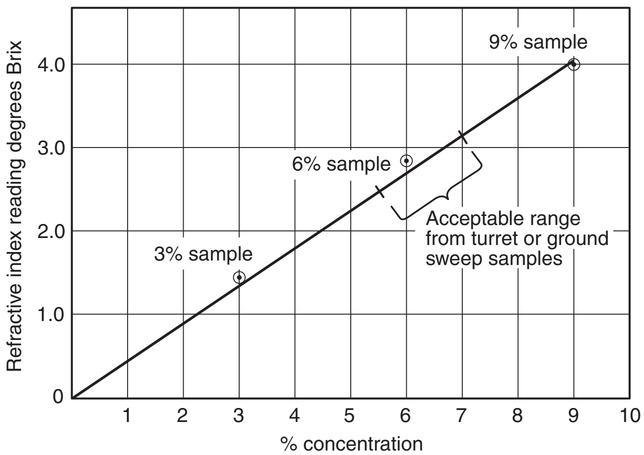

FIGURE A.6.2.2.2.2(b) Typical Graph Using FFFP (6%).

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.

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 µS/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 Since foam is not discharged during input-based testing, Test Method C can only be used to test and determine the foam solution concentration.

The use of a surrogate liquid instead of foam solution might be permitted for the purpose of determining the discharge pattern and maximum range.

When using a surrogate liquid instead of foam solution for the foam pattern and distance, the results should be recorded in both the actual measurements of the surrogate liquid, and as a calculated measurement of the corresponding foam solution discharge. The corresponding foam solution discharge pattern and maximum range measurements should be used for the requirements of this standard.

The corresponding foam pattern and distance should be expressed as a set of multipliers or index numbers relating to each of the relevant measurements and settings. The index numbers might be determined by the vehicle manufacturer, with specification of the vehicle model, foam type, and nozzle type. Alternatively, these index numbers might be established experimentally by the AHJ.

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):

N **[A.6.3.2.2.3]**

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

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:

Δ 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

N **[6.3.2.2.3(B)]**

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

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.

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).

N **[A.6.3.3.2.5]**

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

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.

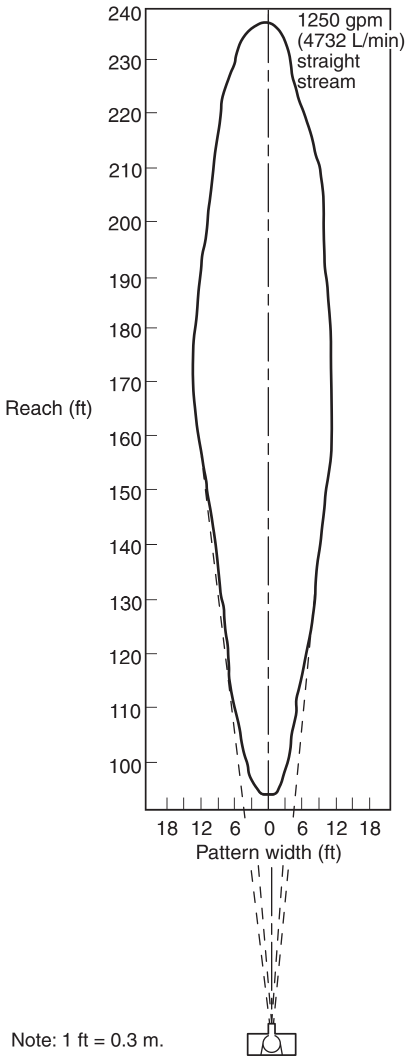

FIGURE A.6.5.2 Typical Foam Discharge Pattern.

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 (°C)] WATER TEMP: .... [°F (°C)]

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.

$$\text{Foam expansion} = \frac{\text{Volume of foam container}}{\text{Net weight of foam sample}}$$

$$= \frac{\text{.......... mL}}{\text{........ grams (from above)}} = \text{.......}$$

$$\text{25\% volume} = \frac{\text{Net weight of foam sample}}{4}$$

$$= \frac{\text{.......... grams (from above)}}{4} = \text{....... mL}$$

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

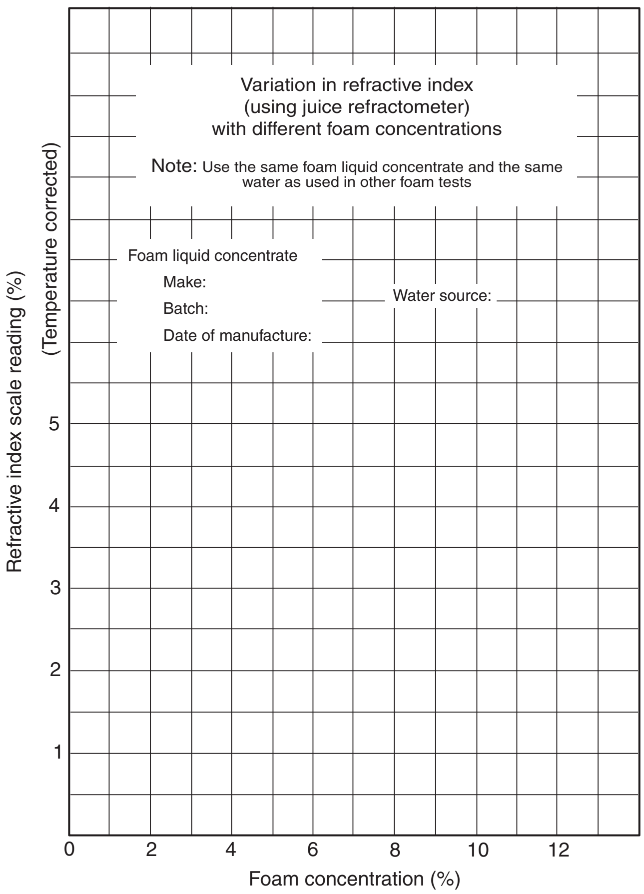

FIGURE A.6.6.1(b) Worksheet for Graphing Results of Foam Physical Properties Test.

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 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.

B.1.2.1 The exact size of the fire to be used is not critical; however, it should not be less than 100 ft^2 (10 ft × 10 ft) [9 m^2 (3 m × 3 m)] in area. Large-scale testing has shown that larger — 11,580 ft^2 (107.8 ft × 107.8 ft) [1075.8 m^2 (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 ft^2 (0.2 m^2) 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 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/ft^2 (Lpm/m^2)].

B.1.2.6 The actual rate is checked by placing 1 ft^2 (0.1 m^2) (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/ft^2 (5.3 Lpm/m^2) for AFFF, 0.20 gpm/ft^2 (8.1 Lpm/m^2) for protein foam, and 0.18 gpm/ft^2 (7.3 Lpm/m^2) 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

N **[B.1.2.7]**

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

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

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

B.1.3 Burnback Test.

Δ **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 U.S. Military Specification MIL-F-24385, *Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF), Liquid Concentrate for Fresh and Sea Water*, or ICAO *Airport Services Manual*, Doc 9137, Part 8, Level B.

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*, 2018 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire-Fighting Vehicles*, 2020 edition.

C.1.2 Other Publications.

N **C.1.2.1 FAA Publications.** Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591. https://www.faa.gov/airports/airport_safety/certalerts/

FAA CertAlert No. 16-09, *Particles in Aqueous Film Forming Foam (AFFF) Tanks on Aircraft Rescue Fire Fighting (ARFF) Vehicles and AFFF Storage Tanks*, 2016.

N **C.1.2.2 ICAO Publications.** International Civil Aviation Organization (ICAO), 999 Robert-Bourassa Boulevard, Montréal, Québec H3C 5H7, Canada.

ICAO DOC 9137, *Airport Services Manual*, Part 8, Airport Operational Services, 2003.

N **C.1.2.3 U.S. Government Publications.** U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

U.S. Military Specification MIL PRF-24385F(SH) with Amendment 2, *Fire Extinguishing Agent, Aqueous Film-Forming Foam (AFFF) Liquid Concentrate, for Fresh and Sea Water,* September 7, 2017.

C.2 Informational References. (Reserved)

C.3 References for Extracts in Informational Sections.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2016 edition.

 Shaded text = Revisions. Δ = Text deletions and figure/table revisions. • = Section deletions. *N* = New material.

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