NFPA 412

Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment

2003 Edition

NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
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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 and acted on by NFPA at its May Association Technical Meeting held May 18–21, 2003, in Dallas, TX. It was issued by the Standards Council on July 18, 2003, with an effective date of August 7, 2003, and supersedes all previous editions.

This edition of NFPA 412 was approved as an American National Standard on July 18, 2003.

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. Additionally, information on using the conductivity meter for determining foam solution concentration was added. 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.

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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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Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

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, Annex C lists the complete title and edition of the source documents for both mandatory and nonmandatory extracts. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. 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 rescue and fire-fighting vehicles designed in accordance with the applicable portions of 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, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 403, *Standard for Aircraft Rescue and Fire-Fighting Services at Airports,* 2003 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire-Fighting Vehicles,* 2001 edition.

2.3 Other Publications. (Reserved)

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 included, common usage of the terms shall apply.

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 shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

3.3.1 Foam. Fire-fighting foam, within the scope of this standard, is a stable aggregation of small bubbles of lower density than oil or water that exhibits a tenacity for covering horizontal surfaces. 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.

3.3.1.1 *Alcohol-Resistant Foam.* Used for fighting fires involving water-soluble materials or fuels that are destructive to other types of foams. Some alcohol-resistant foams may be capable of forming a vapor-suppressing aqueous film on the surface of hydrocarbon fuels.

3.3.1.2 *Aqueous Film-Forming Foam (AFFF) Concentrate.* A concentrated aqueous solution of one or more hydrocarbon or fluorochemical surfactants that forms a foam capable of producing a vapor-suppressing aqueous film on the surface of hydrocarbon fuels. The foam produced from AFFF concentrates is dry-chemical compatible and is therefore suitable for use in combination with that agent.

3.3.1.3 *Film-Forming Fluoroprotein (FFFP) Foam Concentrate.* A protein-based foam concentrate incorporating fluorinated surfactants that forms a foam capable of producing a vapor-suppressing aqueous film on the surface of hydrocarbon fuels. This foam may show an acceptable level of compatibility with dry chemicals and may be suitable for use with those agents.

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. Foam concentrate is a concentrated liquid foaming agent as received from the manufacturer. For the purpose of this document, "foam concentrate" and "concentrate" are used interchangeably. [**11:**3.3]

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.

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

4.1 Foam and Foam System Tests.

4.1.1 The expansion ratio and 25 percent drainage time are the foam characteristics that shall be determined. Additionally, the foam concentration shall be determined, both as a test of the vehicle proportioning system and to establish the legitimacy of the expansion and drainage data obtained. Foam distribution patterns shall be determined for use in calculating the area of fire that the vehicle is capable of controlling.

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.

4.2.2 Foam samples shall be obtained by the methods given in 6.3.1.3 of this standard.

4.2.3 Foam samples shall be analyzed for expansion and drainage time using the criteria specified in Section 5.1 of this standard.

4.2.4 Foam samples shall be analyzed for concentration as specified in Section 5.2 of this standard.

4.3 Undertruck Nozzles.

4.3.1 The foam distribution pattern shall provide protection for the area beneath the vehicle.

4.3.2 Foam samples shall be collected and analyzed for concentration as specified in Section 5.2 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 shall 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

5.2 Foam Solution Concentration.

5.2.1 Foam solution concentration shall be tested in accordance with Section 6.2 of this standard.

5.2.2* 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.

5.2.3 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.

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)*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. 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 or 6.2.3. When testing foam concentration from vehicles, the lowest flow rate outlet shall be tested first. One handheld refractometer or one handheld conductivity meter suitable for the foam concentrate being tested shall be used. Method B (in 6.2.3) shall be used only when using a refractometer. 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. Or, if using conductivity, the probe shall be dipped into the sample and the digital scale read.

6.2.2* Method A (Refractometer or Conductivity Meter). A calibration curve shall be prepared using the following apparatus and procedure.

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

(1) Three 100-mL graduates
(2) One measuring pipette (10-mL capacity)
(3) One 100-mL beaker
(4) One 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 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 100-mL mark with water. After thoroughly mixing, a refractive index reading shall be taken of each standard. A plot shall be made on graph paper of the scale reading against the known foam solution concentrates and shall serve as a calibration curve for this particular series of foam tests.

6.2.2.3* Test Sample Concentration. 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. 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 (Refractometer Only). A calculation shall be made using the following apparatus and procedure.

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

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. Determine the foam concentration of the foam solution sample by calculating the following formula using the readings obtained in steps (4), (6), and (8) above:

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

6.3 Foam Tests.

6.3.1 General Requirements for Expansion and Drainage Methods.

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 (–16°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 (–16°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 (–16°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. This shall be accomplished by placing a foam sample collector in the center of the ground pattern as determined in the nozzle pattern test.

6.3.2* 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.

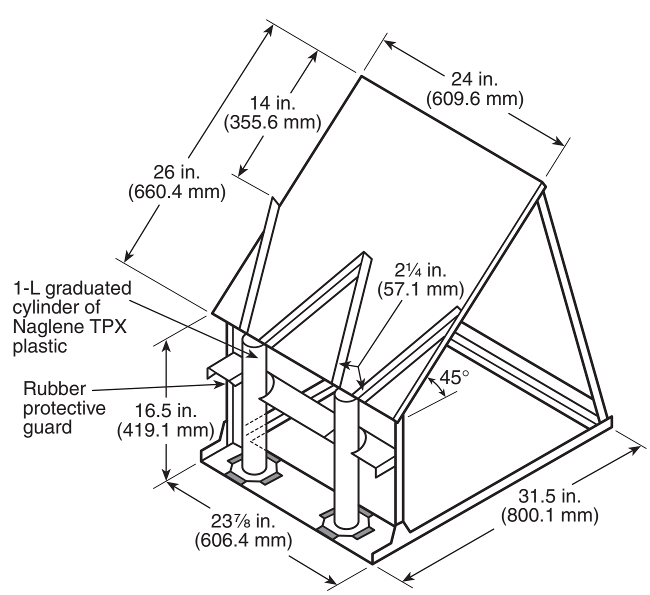

FIGURE 6.3.2.1.1 AFFF Sample Collector.

6.3.2.1.2 The foam sample shall be collected in a standard 1000-mL-capacity graduated cylinder. The cylinder shall be cut off at the 1000-mL mark to ensure a fixed volume of foam as a sample. The cylinder shall be marked in 10-mL graduations below the 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 balance having a maximum capacity sufficient to weigh the foam sample container and the foam sample. The foam sample collector shall then be located in the center of the discharge pattern determined in Section 6.5. 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. 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. 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 straight edge, and any remaining foam wiped from the outside surface of the container. The container shall then be placed on the balance. The total weight of the foam sample and container shall be determined to the nearest gram. 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. The weight of the foam sample in grams shall be divided by 4 to obtain the equivalent 25 percent drainage volume in milliliters.

6.3.2.2.3* The foam sample container shall be placed on a level surface at a convenient height. At 30-second intervals, the level of accumulated solution in the bottom of the cylinder shall be noted and recorded. The drainage time versus the volume relationship shall be recorded until the 25 percent volume has been exceeded. The 25 percent drainage time shall then be interpolated from the data.

6.3.2.2.4 Foam samples of the foam shall be weighed to the nearest gram. The expansion of the foam shall be calculated by the following equation:

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

6.3.3 Test Method B.

6.3.3.1 Foam Sampling Apparatus.

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

6.3.3.1.2 The foam sample shall be collected in a cylindrical 1600-mL container. The foam sample container shall be constructed as specified in Figure 6.3.3.1.2.

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 balance having a maximum capacity sufficient to weigh the foam sample container, on a suitable support, and the foam sample. The foam sample collector shall then be located in the center of the discharge pattern determined in Section 6.5 of this standard. 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. 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. 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.

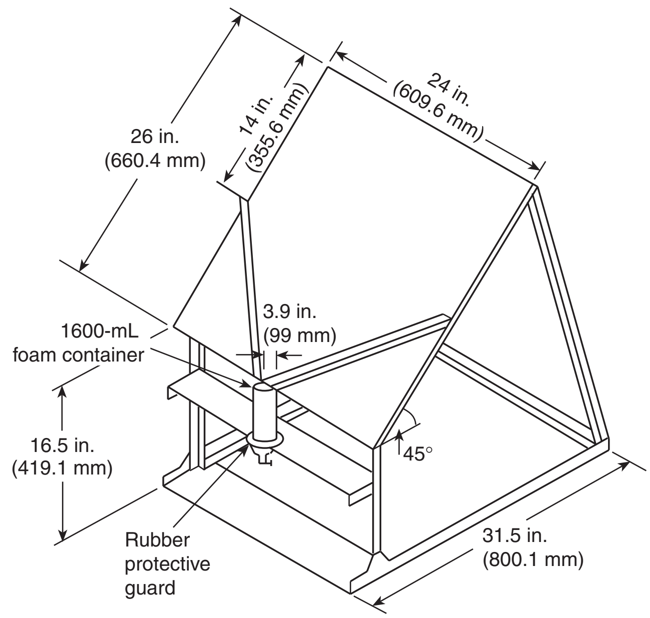

FIGURE 6.3.3.1.1 Foam Sample Collector.

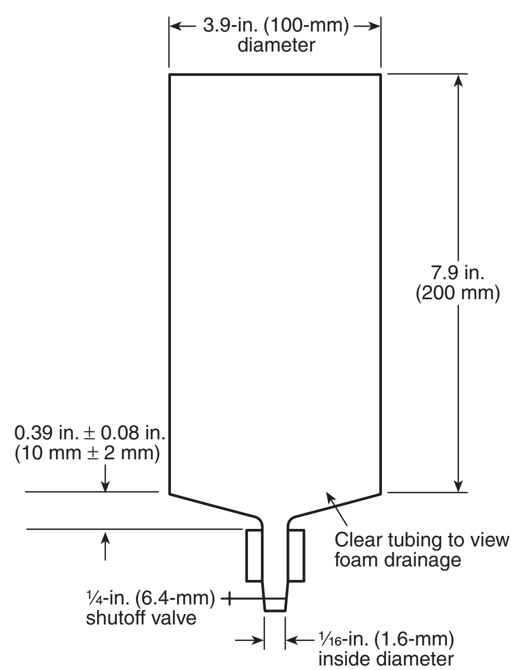

FIGURE 6.3.3.1.2 1600-mL Foam Sample Container.

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 straight edge, and any remaining foam wiped from the outside surface of the container. The container shall then be placed on the balance. The total weight of the foam sample and container shall be determined to the nearest gram. 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. 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. 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. If the expected expansion ratio is more than 5:1, then a 100-mL graduated cylinder shall be used to collect the drainage; if the expected expansion ratio is 5:1 or less, then a 250-mL graduated cylinder shall be used.

6.3.3.2.4* Foam samples shall be weighed to the nearest gram. The expansion of the foam shall be calculated by the following equation:

$$\text{Expansion} = \frac{1600}{(\text{full weight}) - (\text{empty weight in grams})}$$

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. 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. The test shall be conducted under wind conditions of 5 mph (8 km/h) or less. 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. 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. For purposes of defining the edge of the pattern, any foam less than ½ in. (12.7 mm) in depth shall be disregarded. Distances between markers shall be plotted on graph paper. The vertical axis shall show the reach, and the horizontal axis shall show the pattern width, for each nozzle setting. 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.5.2.2 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).

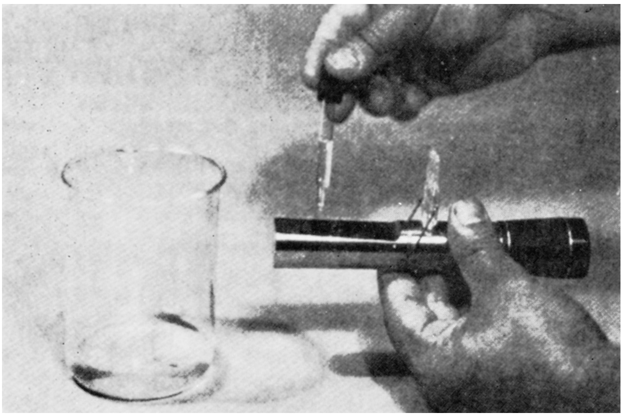

FIGURE A.6.2.2(a) Measuring the Index of Refraction by Placing a Few Drops of the Solution to Be Tested on the Prism of a Refractometer and Closing the Cover Plate. This Is a Typical Refractometer Suitable for this Purpose.

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.

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 5.2.2 and 5.2.3. Examples include one handheld refractometer — American Optical Co. Model No. 10430 or equivalent — or one handheld conductivity meter — Omega Model CDH-70 or equivalent. ATAGO Co. Ltd. Model No. N10, AO Model No. 10441, or equivalent showing 0–10 on the Brix scale is recommended to enable low readings given by AFFF solutions to be read easily.

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.

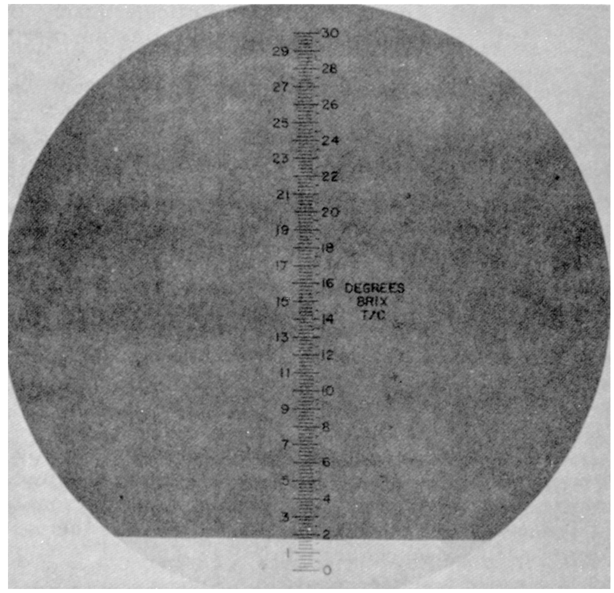

FIGURE A.6.2.2(c) Illustrating the Field of View by Looking Into the Refractometer Shown in Figures A.6.2.2(a) and A.6.2.2(b) Containing a 6 Percent AFFF Solution. The Dark Intersects the Scale at 1.7, and this Value Is Recorded as the Reading for a 6 Percent Concentration.

This is particularly true when using 1 percent and 3 percent foam concentrates.

A.6.3.2 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.6.3.2(a) shows a typical graph using 6 percent AFFF solution and Figure A.6.3.2(b) shows a typical graph using a 6 percent FFFP solution.

A.6.3.2.2.3 The following 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 1 mL, the total volume of foam solution contained in the given foam sample is 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.

Table A.6.3.2.2.3 Drainage Time

Time (min:sec)	Assumed Drained Solution Volume (mL)
0:00	0
0:30	10
1:00	20
1:30	30
2:00	40
2:30	50
3:00	60

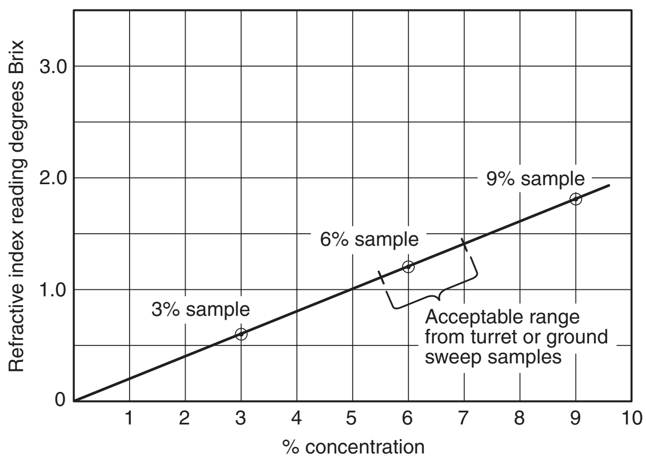

FIGURE A.6.3.2(a) Typical Graph Using AFFF (6%).

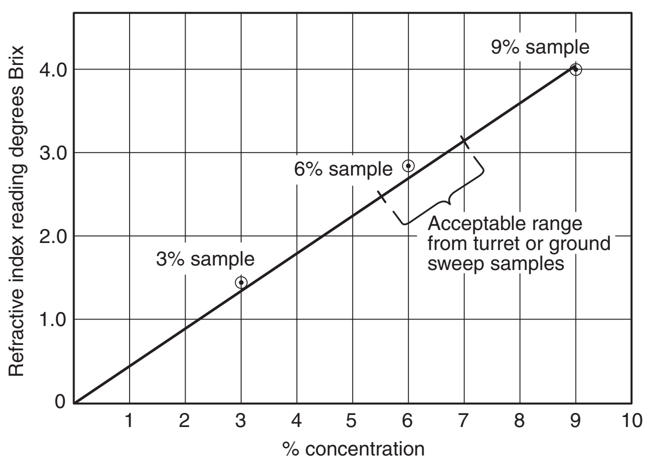

FIGURE A.6.3.2(b) Typical Graph Using FFFP (6%).

It is seen that the 25 percent volume of 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:

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

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

A.6.3.3.2.4 The following shows the calculation of expansion. The net weight of the foam sample (see drainage example) is assumed to be 200 g; therefore, the volume of foam solution contained in the 1600-mL foam sample is 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.

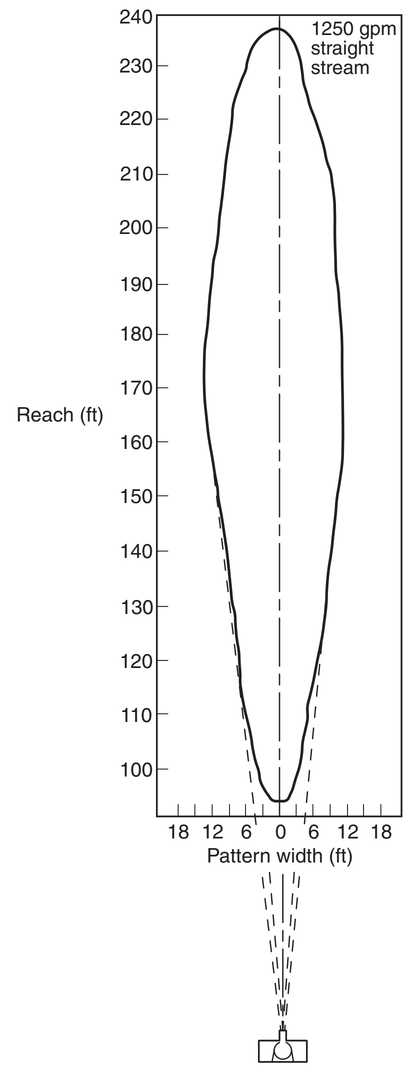

FIGURE A.6.5.2 Typical Foam Discharge Pattern.

FOAM PHYSICAL PROPERTY TESTS WORK SHEET
(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.

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

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

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

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

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

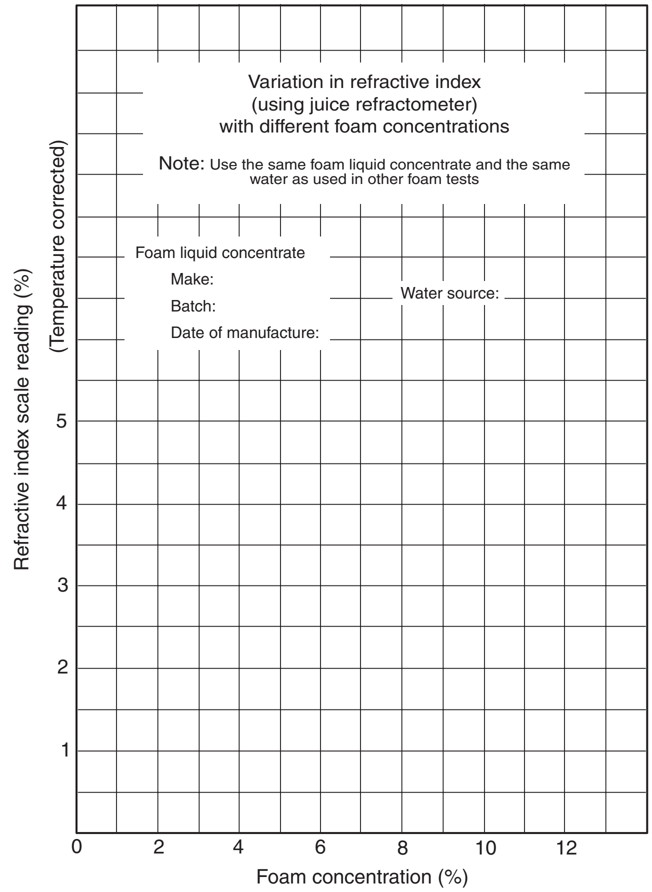

FIGURE A.6.6.1(b) Work Sheet for Graphing Results of Foam Physical Properties Test.

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.

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 9 m^2 (3 m × 3 m) [100 ft^2 (10 ft × 10 ft)] in area. Large-scale testing has shown that larger — 1075.8 m^2 (32.8 m × 32.8 m) [11,580 ft^2 (107.8 ft × 107.8 ft)] — 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
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. To standardize this, a short section of stovepipe 12 in. in diameter is dropped into the foam blanket like a cookie cutter. The foam is removed from the inside, and the fuel surface is ignited and allowed to burn for 1 minute before the stovepipe is removed. The rate of enlargement of the fire is then observed. A long period of confinement is desired. The delay period after end of foam application and start of re-ignition can be varied, but for comparative tests, it must be kept constant.

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 following documents or portions thereof are referenced within this standard for informational purposes only and are thus not part of the requirements of this document unless also listed in Chapter 2.

C.1.1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 403, *Standard for Aircraft Rescue and Fire-Fighting Services at Airports*, 2003 edition.

C.1.2 Other Publications. (Reserved)

C.2 Informational References. (Reserved)

C.3 References for Extracts. The following documents are listed here to provide reference information, including title and edition, for extracts given throughout this standard as indicated by a reference in brackets [ ] following a section or paragraph. These documents are not a part of the requirements of this document unless also listed in Chapter 2 for other reasons.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2002 edition.

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