NFPA 11
Standard for Low-Expansion Foam

1998 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

IMPORTANT NOTICE ABOUT THIS DOCUMENT

NFPA codes, standards, recommended practices, and guides, of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its codes and standards.

The NFPA disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this document. The NFPA also makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this document available, the NFPA is not undertaking to render professional or other services for or on behalf of any person or entity. Nor is the NFPA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

The NFPA has no power, nor does it undertake, to police or enforce compliance with the contents of this document. Nor does the NFPA list, certify, test or inspect products, designs, or installations for compliance with this document. Any certification or other statement of compliance with the requirements of this document shall not be attributable to the NFPA and is solely the responsibility of the certifier or maker of the statement.

NOTICES

All questions or other communications relating to this document and all requests for information on NFPA procedures governing its codes and standards development process, including information on the procedures for requesting Formal Interpretations, for proposing Tentative Interim Amendments, and for proposing revisions to NFPA documents during regular revision cycles, should be sent to NFPA headquarters, addressed to the attention of the Secretary, Standards Council, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

Users of this document should be aware that this document may be amended from time to time through the issuance of Tentative Interim Amendments, and that an official NFPA document at any point in time consists of the current edition of the document together with any Tentative Interim Amendments then in effect. In order to determine whether this document is the current edition and whether it has been amended through the issuance of Tentative Interim Amendments, consult appropriate NFPA publications such as the *National Fire Codes*® Subscription Service, visit the NFPA website at www.nfpa.org, or contact the NFPA at the address listed above.

A statement, written or oral, that is not processed in accordance with Section 5 of the Regulations Governing Committee Projects shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

The NFPA does not take any position with respect to the validity of any patent rights asserted in connection with any items which are mentioned in or are the subject of this document, and the NFPA disclaims liability for the infringement of any patent resulting from the use of or reliance on this document. Users of this document are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Users of this document should consult applicable federal, state, and local laws and regulations. NFPA does not, by the publication of this document, intend to urge action that is not in compliance with applicable laws, and this document may not be construed as doing so.

NFPA 11

Standard for

Low-Expansion Foam

1998 Edition

This edition of NFPA 11, *Standard for Low-Expansion Foam,* was prepared by the Technical Committee on Foam and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 17-19, 1997, in Kansas City, MO. It was issued by the Standards Council on January 16, 1998, with an effective date of February 6, 1998, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 11 was approved as an American National Standard on March 31, 1998.

Origin and Development of NFPA 11

NFPA committee activity in this field dates from 1921 when the Committee on Manufacturing Risks and Special Hazards prepared standards on foam as a section of the general *Standard on Protection of Fire Hazards, Incident to the Use of Volatiles in Manufacturing Processes.* Subsequently the standards were successively under the jurisdiction of the Committee on Manufacturing Hazards and the Committee on Special Extinguishing Systems, prior to the present committee organization. The present text supersedes the prior editions adopted in 1922, 1926, 1931, 1936, 1942, 1950, 1954, 1959, 1960, 1963, 1969, 1970, 1972, 1973, 1974, 1975, 1976, and 1978. It also supersedes the 1977 edition of NFPA 11B.

The 1983 edition was completely rewritten to include all the material formerly contained in NFPA 11B, *Standard on Synthetic and Combined Agent Systems.* The standard was revised in 1988 and again in 1994 to more clearly state the requirements and to separate mandatory requirements from advisory text.

The standard has been revised for the 1998 edition to include requirements for foam systems for marine applications and to provide guidance relating to the environmental impact of foam system discharges.

Technical Committee on Foam

Christopher P. Hanauska, *Chair*
Hughes Assoc. Inc., MN [SE]

Laurence D. Watrous, *Secretary*
HSB Professional Loss Control, TN [I]

William M. Carey, Underwriters Laboratories Inc., IL, [RT]
Salvatore A. Chines, Industrial Risk Insurers, CT [I]
Rep. Industrial Risk Insurers
W. D. Cochran, Houston, TX [SE]
Gene DiClementi, Glenview Fire Dept., IL [E]
Arthur R. Dooley, Dooley Tackaberry, Inc., TX [IM]
Rep. Nat'l Assn. of Fire Equipment Distributors Inc.
Francis X. Dunigan, Angus Fire North America, NC [M]
John A. Frank, Kemper Nat'l Insurance Cos., GA [I]
Robert A. Green, Public Service Electric & Gas Co., NJ [U]
Rep. Edison Electric Inst.
Larry Jesclard, Engineered Fire Systems, Inc., AK [IM]
Rep. Fire Suppression Systems Assn.
Dennis C. Kennedy, Rolf Jensen & Assoc. Inc., IL [SE]
John A. Krembs, M&M Protection Consultants, IL [I]
John N. McConnell, Chemguard, Inc., TX [M]
Rep. American Fire Sprinkler Assn., Inc.
Robert C. Merritt, Factory Mutual Research Corp., MA [I]
Richard F. Murphy, Cranford, NJ [SE]
Francisco N. Nazario, Exxon Research & Engr Co., NJ [U]
Rep. American Petroleum Inst.
Edward C. Norman, Aqueous Foam Technology, Inc., PA [SE]
Keith Olson, Tyco Int'l Ltd., WI [M]
Richard E. Ottman, 3M/Specialty Chemical Division, MN [M]
Fay Purvis, Nat'l Foam, Inc., PA [M]
Niall Ramsden, Resource Protection Int'l, England [SE]
Tom Reser, Edwards Mfg. Inc., OR [M]
Howard L. Vandersall, Lawdon Fire Services, Inc., CA [SE]
Klaus Wahle, U.S. Coast Guard, DC [E]
B. J. Walker, Walker & Assoc., MO [SE]
Joseph O. Welch, Emergency One, Inc., FL [M]
Michel Williams, Ultramar Canada, Inc., Canada [U]
Rep. NFPA Industrial Fire Protection Section
Jack Woycheese, Gage-Babcock & Assoc. Inc., CA [SE]

Alternates

William M. Cline, Factory Mutual Research Corp., MA [I]
(Alt. to R. C. Merritt)
Donald R. Coy, 3M/Specialty Chemical Division, MN [M]
(Alt. to R. E. Ottman)
Dennis L. Doherty, Industrial Risk Insurers, CT [I]
(Alt. to S. A. Chines)
Brian R. Foster, HSB Professional Loss Control, FL [I]
(Alt. to L. D. Watrous)
Peter E. Getchell, Kemper Nat'l Insurance Cos., PA [I]
(Alt to J. A. Frank)
Matthew T. Gustafson, U.S. Coast Guard, DC [E]
(Alt. to K. Wahle)
Kevin P. Kuntz, M&M Protection Consultants, NJ [I]
(Alt. to J. A. Krembs)
Norbert W. Makowka, Nat'l Assn. of Fire Equipment Distributors (NAFED), IL [IM]
(Alt to A. R. Dooley)
Terry Planck, Emergency One, Inc., FL [M]
(Alt. to J. O. Welch)
David K. Riggs, SOTEC, LA [IM]
(Alt. to L. Jesclard)
Joseph L. Scheffey, Hughes Assoc. Inc., MD [SE]
(Alt. to C. P. Hanauska)
Steven F. Vieira, Tyco Int'l Ltd., RI [M]
(Alt. to K. Olson)
Christopher L. Vollman, Rolf Jensen & Assoc. Inc., TX [SE]
(Alt. to D. C. Kennedy)
Edward A. Watson, Exxon Research & Engr Co., NJ [U]
(Alt. to F. N. Nazario)
Kenneth W. Zastrow, Underwriters Laboratories Inc., IL [RT]
(Alt. to W. M. Carey)

Nonvoting

D. N. Meldrum, Malvern, PA
(Member Emeritus)

David R. Hague, NFPA Staff Liaison

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

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

Committee Scope: This Committee shall have primary responsibility for documents on the installation, maintenance, and use of foam systems for fire protection, including foam hose streams.

Contents

NFPA 11

Standard for

Low-Expansion Foam

1998 Edition

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

Information on referenced publications can be found in Chapter 9 and Appendix G.

FOREWORD

Fire-fighting foam is an aggregate of air-filled bubbles formed from aqueous solutions and is lower in density than flammable liquids. It is used principally to form a cohesive floating blanket on flammable and combustible liquids and prevents or extinguishes fire by excluding air and cooling the fuel. It also prevents reignition by suppressing formation of flammable vapors. It has the property of adhering to surfaces, which provides a degree of exposure protection from adjacent fires.

Foam can be used as a fire prevention, control, or extinguishing agent for flammable liquid hazards. Foam for these hazards can be supplied by fixed piped systems or portable foam-generating systems. Foam can be applied through foam discharge outlets, which allow it to fall gently on the surface of the burning fuel. Foam can also be applied by portable hose streams using foam nozzles or large-capacity monitor nozzles or subsurface injection systems.

Foam can be supplied by overhead piped systems for protection of hazardous occupancies associated with potential flammable liquid spills in the proximity of high-value equipment or for protection of large areas. The foam used for flammable liquid spills is in the form of a spray or dense "snowstorm." The foam particles coalesce on the surface of the burning fuel after falling from the overhead foam outlets, which are spaced to cover the entire area at a uniform density. (For systems required to meet both foam and water spray design criteria, see NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems.*

Large-spill flammable liquid fires can be fought with mobile equipment, such as an aircraft crash truck or industrial foam truck equipped with agent and equipment capable of generating large volumes of foam at high rates. Foam for this type of hazard can be delivered as a solid stream or in a dispersed pattern. (Standards for industrial foam trucks include NFPA 11C, *Standard for Mobile Foam Apparatus*, and standards for aircraft crash trucks include NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles.*)

Foam does not break down readily and, when applied at an adequate rate, has the ability to extinguish fire progressively. As application continues, foam flows easily across the burning surface in the form of a tight blanket, preventing reignition on the surfaces already extinguished.

Foam is not suitable for three-dimensional flowing liquid fuel fires or for gas fires.

Chapter 1 General

1-1 Scope. This standard covers the characteristics of foam-producing materials used for fire protection and the requirements for the design, installation, operation, testing, and maintenance of equipment and systems, for flammable and combustible liquid hazards and local areas within buildings, and storage tanks and indoor and outdoor processing areas.

It is not the intent of this standard to specify where foam protection is required. (To determine where foam protection is required, see applicable standards such as NFPA 30, *Flammable and Combustible Liquids Code.*)

Foam can be applied to protect the surface of a flammable liquid that is not burning. The foam concentrate manufacturer shall be consulted to determine the optimum method of application, rate of discharge, application density, and frequency of reapplication required to establish and maintain the integrity of the foam blanket.

This standard is not applicable to the following types of systems:

(a) Chemical foams and systems (considered obsolete)

(b) Deluge foam-water sprinkler or spray systems *(See NFPA 16, Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems.)*

(c) Foam-water closed-head sprinkler systems *(See NFPA 16A, Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems.)*

(d) Combined agent systems

(e) Mobile foam apparatus *(See NFPA 11C, Standard for Mobile Foam Apparatus and NFPA 1901, Standard for Pumper Fire Apparatus.)*

(f) Medium- and high-expansion foam systems *(See NFPA 11A, Standard for Medium- and High-Expansion Foam Systems.)*

(g) Class A foam and systems *(See NFPA 298, Standard on Fire Fighting Foam Chemicals for Class A Fuels in Rural, Suburban, and Vegetated Areas.)*

1-2 Purpose. This standard is intended for the use and guidance of those responsible for designing, installing, testing, inspecting, approving, listing, operating, or maintaining fixed, semifixed, or portable foam fire-extinguishing systems for interior or exterior hazards. Nothing in this standard is intended to restrict new technologies or alternative arrangements, provided the level of safety prescribed by the standard is not lowered.

1-3 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The liter unit, which is not part of but is recognized by SI, is commonly used in international fire protection. Conversion factors for this unit are found in Table 1-3.

Table 1-3 Metric Units of Measure

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 3.785 L
liter per minute per square meter	$L/min \cdot m^2$	1 gpm/ft^2 = 40.746 $L/min \cdot m^2$
cubic decimeter	dm^3	1 gal = 3.785 dm^3
pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 105 Pa
kilopascal	kPa	1 psi = 6.895 kPa

Note: For additional conversions and information, see ASTM E 380, *Standard for Metric Practice.*

1-4 Definitions.

Air-Aspirating Discharge Devices. These devices are specially designed to aspirate and mix air into the foam solution to generate foam. The foam then is discharged in a specific design pattern.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Concentration. The percent of foam concentrate contained in a foam solution. The type of foam concentrate used determines the percentage of concentration required. For example, a 3 percent foam concentrate is mixed in the ratio of 97 parts water to 3 parts foam concentrate to make foam solution.

Discharge Device. A fixed, semifixed, or portable device that directs the flow of foam to the fire or flammable liquid surface.

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

Expansion. The ratio of final foam volume to original foam solution volume.

Fixed Foam Discharge Outlet. A device permanently attached to a tank, dike, or other containment structure, designed to introduce foam.

Fixed Monitor (Cannon). A device that delivers a large foam stream and is mounted on a stationary support that either is elevated or is at grade. The monitor can be fed solution by permanent piping or hose.

Flammable and Combustible Liquids. Flammable liquids shall be or shall include any liquids having a flash point below 100°F (37.8°C) and having a vapor pressure not exceeding 40 psi (276 kPa) (absolute) at 100°F (37.8°C). Flammable liquids shall be subdivided as follows:

(a) Class I liquids shall include those having flash points below 100°F (37.8°C) and shall be subdivided as follows:

1. Class IA liquids shall include those having flash points below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C).
2. Class IB liquids shall include those having flash points below 73°F (22.8°C) and having a boiling point above 100°F (37.8°C).
3. Class IC liquids shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

Combustible liquids shall be or shall include any liquids having a flash point at or above 100°F (37.8°C). They shall be subdivided as follows:

(a) Class II liquids shall include those having flash points at or above 100°F (37.8°C) and below 140°F (60°C).

(b) Class IIIA liquids shall include those having flash points at or above 140°F (60°C) and below 200°F (93.3°C).

(c) Class IIIB liquids shall include those having flash points at or above 200°F (93.3°C).

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. Foams also are defined by expansion and are arbitrarily subdivided into three ranges of expansion. These ranges correspond broadly to certain types of usage described below. The three ranges are as follows:

(a) Low-expansion foam — expansion up to 20

(b) Medium-expansion foam — expansion from 20 to 200

(c) High-expansion foam — expansion from 200 to 1000

Foam Chamber. See Fixed Foam Discharge Outlet.

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.

(a) *Protein-Foam Concentrates.* Protein-foam concentrates consist primarily of products from a protein hydrolysate, plus stabilizing additives and inhibitors to protect against freezing, to prevent corrosion of equipment and containers, to resist bacterial decomposition, to control viscosity, and to otherwise ensure readiness for use under emergency conditions. They are diluted with water to form 3 percent to 6 percent solutions depending on the type. These concentrates are compatible with certain dry chemicals.

(b) *Fluoroprotein-Foam Concentrates.* Fluoroprotein-foam concentrates are very similar to protein-foam concentrates but have a synthetic fluorinated surfactant additive. In addition to an air-excluding foam blanket, they also can deposit a vaporization-preventing film on the surface of a liquid fuel. They are diluted with water to form 3 percent to 6 percent solutions depending on the type. These concentrates are compatible with certain dry chemicals.

(c) *Synthetic-Foam Concentrates.* Synthetic-foam concentrates are based on foaming agents other than hydrolyzed proteins and include the following:

1. *Aqueous Film-Forming Foam (AFFF) Concentrates.* These concentrates are based on fluorinated surfactants plus foam stabilizers and usually are diluted with water to a 1 percent, 3 percent, or 6 percent solution. The foam formed acts as a barrier both to exclude air or oxygen and to develop an aqueous film on the fuel surface that is capable of suppressing the evolution of fuel vapors. The foam produced with AFFF concentrate is dry chemical compatible and thus is suitable for combined use with dry chemicals.

2. *Medium- and High-Expansion Foam Concentrates.* These concentrates, which are usually derived from hydrocarbon surfactants, are used in specially designed equipment to produce foams having foam-to-solution volume ratios of 20:1 to approximately 1000:1. This equipment can be air-aspirating or blower-fan type. Guidance for the use of these materials is provided in NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems.*

3. *Other Synthetic-Foam Concentrates.* Other synthetic-foam concentrates also are based on hydrocarbon surface active agents and are listed as wetting agents, foaming agents, or both. In general, their use is limited to portable nozzle foam application for spill fires within the scope of their listings. The appropriate listings shall be consulted to determine proper application rates and methods. *(See NFPA 18, Standard on Wetting Agents.)*

(d) *Film-Forming Fluoroprotein (FFFP) Foam Concentrates.* These concentrates use fluorinated surfactants to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors. This type of foam utilizes a protein base plus stabilizing additives and inhibitors to protect against freezing, corrosion, and bacterial decomposition, and it also resists fuel pickup. The foam is usually diluted with water to a 3 percent or 6 percent solution and is dry chemical compatible.

(e) *Alcohol-Resistant Foam Concentrates.* These concentrates are 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. There are three general types. One is based on water-soluble natural polymers, such as protein or fluoroprotein concentrates, and also contains alcohol-insoluble materials that precipitate as an insoluble barrier in the bubble structure.

The second type is based on synthetic concentrates and contains a gelling agent that surrounds the foam bubbles and forms a protective raft on the surface of water-soluble fuels; these foams can also have film-forming characteristics on hydrocarbon fuels.

The third type is based on both water-soluble natural polymers, such as fluoroprotein, and contains a gelling agent that protects the foam from water-soluble fuels. This foam can also have film-forming and fluoroprotein characteristics on hydrocarbon fuels.

Alcohol-resistant foam concentrates are generally used in concentrations of 3 to 10 percent solutions, depending on the nature of the hazard to be protected and the type of concentrate.

Foam-Generating Methods.* The methods of generation of air foam recognized in this standard include the following:

(a) *Foam Hose Stream.* A foam stream from a handline.

(b) *Foam Nozzles or Fixed Foam Makers.* A specially designed hoseline nozzle or fixed foam maker designed to aspirate air that is connected to a supply of foam solution. They are constructed so that one or several streams of foam solution issue into a space with free access to air. Part of the energy of the liquid is used to aspirate air into the stream, and turbulence downstream of this point creates a stable foam capable of being directed to the hazard being protected. Various types of devices can be installed at the end of the nozzle to cause the foam to issue in a wide pattern or a compacted stream.

(c) *Pressure Foam Maker (High Back-Pressure or Forcing Type).* A foam maker utilizing the venturi principle for aspirating air into a stream of foam solution forms foam under pressure. Sufficient velocity energy is conserved in this device so that the resulting foam can be conducted through piping or hose to the hazard being protected.

(d) *Foam Monitor Stream.* A large capacity foam stream from a nozzle that is supported in position and can be directed by one person.

Foam Solution. A homogeneous mixture of water and foam concentrate in the proper proportions. For the purpose of this document, "foam solution" and "solution" are used interchangeably.

Handline. A hose and nozzle that can be held and directed by hand. The nozzle reaction usually limits the solution flow to about 300 gpm (1135 L/min).

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

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

Non-Air-Aspirating Discharge Devices. These devices are designed to provide a specific water discharge pattern. When discharging AFFF or FFFP solution, they generate an effective AFFF or FFFP with a discharge pattern similar to the water discharge pattern.

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

Premixed Foam Solution. Premixed solution is produced by introducing a measured amount of foam concentrate into a given amount of water in a storage tank.

Proportioning. Proportioning is the continuous introduction of foam concentrate at the recommended ratio into the water stream to form foam solution.

Proportioning Methods for Air Foam Systems. The methods of proportioning used to create the proper solution of water and foam liquid concentrate recognized by this standard include the following:

(a) *Coupled Water-Motor Pump.* A suitably designed positive displacement pump in the water supply line is coupled to a second, smaller, positive displacement foam concentrate pump to provide proportioning.

(b) *Foam Nozzle Eductor.* A suitably designed venturi with "pickup tube" is included in the foam nozzle construction so that foam liquid concentrate is drawn up through a short length of pipe or flexible tubing connecting the foam nozzle with the container of foam concentrate. The concentrate is thus automatically mixed with the water in recommended proportions.

(c) *In-Line Eductor.** A venturi eductor is located in the water supply line to the foam maker. The eductor is connected by single or multiple lines to the source of foam concentrate. It is precalibrated, and it could be adjustable.

(d) *Metered Proportioning.** A separate foam concentrate pump is used to inject foam concentrate into the water stream. Orifices or Venturis, or both, control or measure the proportion of water to foam concentrate. Either manual or automatic adjustment of foam concentrate injection by pressure or flow control can be utilized. Another type of proportioning uses a pump or diaphragm tank to balance the pressure of the water and the concentrate. Variable orifices proportion automatically through a wide range of solution requirements.

(e) *Pressure Proportioning Tank.** A suitable method is provided for displacing foam concentrate from a closed tank by water (with or without a diaphragm separator), using water flow through a venturi orifice.

(f) *Pump Proportioner (Around-the-Pump Proportioner).** The pressure drop between the discharge and suction side of the water pump of the system is used to induct foam concentrate into water by suitable variable or fixed orifices connected to a venturi inductor in a bypass between the pump suction and the pump discharge.

Semisubsurface Foam Injection. Discharge of foam at the liquid surface within a storage tank from a floating hose that rises from a piped container near the tank bottom.

Shall. Indicates a mandatory requirement.

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, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Subsurface Foam Injection. Discharge of foam into a storage tank from an outlet near the tank bottom.

Type I Discharge Outlet.* An approved discharge outlet that conducts and delivers foam gently onto the liquid surface without submergence of the foam or agitation of the surface.

Type II Discharge Outlet. An approved discharge outlet that does not deliver foam gently onto the liquid surface but is designed to lessen submergence of the foam and agitation of the surface.

Chapter 2 System Components and System Types

2-1 General.

2-1.1 A foam system consists of a water supply, a foam concentrate supply, proportioning equipment, a piping system, foam makers, and discharge devices designed to distribute foam effectively over the hazard. Some systems include detection devices. This chapter provides requirements for the correct use of these foam system components.

2-1.2 All components shall be listed for their intended use.

Exception: Where listings for components do not exist, components shall be approved.

2-2 Water Supplies.

2-2.1 Water Supplies, Including Premix Solution.

2-2.1.1 Quality. The water supply to foam systems can be hard or soft, fresh or salt, but shall be of suitable quality so that adverse effects on foam formation or foam stability do not occur. No corrosion inhibitors, emulsion breaking chemicals, or any other additives shall be present without prior consultation with the foam concentrate supplier.

2-2.1.2* Quantity. The water supply shall be adequate in quantity to supply all the devices that might be used simultaneously for the specified time. This includes not only the volume required for the foam apparatus but also water that might be used in other fire-fighting operations, in addition to the normal plant requirements. Premixed solution-type systems need not be provided with a continuous water supply.

2-2.1.3 Pressure. The pressure available at the inlet to the foam system (e.g., foam generator, air foam maker, etc.) under required flow conditions shall be at least the minimum pressure for which the system has been designed.

2-2.1.4 Temperature. Optimum foam production is obtained using water at temperatures between 40°F (4°C) and 100°F (37.8°C). Higher or lower water temperatures can reduce foam efficiency.

2-2.1.5 Design. The water system shall be designed and installed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*. Where solids of sufficient size to obstruct openings or damage the foam equipment might be present, strainers shall be provided. Hydrants furnishing the water supply for foam equipment shall be provided in sufficient number and shall be located as required by the authority having jurisdiction.

2-2.1.6 Storage. Water supply or premixed solution shall be protected against freezing in climates where freezing temperatures can be expected.

2-2.2 Water Pumps. When water pumps are required for foam system operation, they shall be designed and installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

2-3 Foam Concentrates.

2-3.1 Types of Foam Concentrate. Foam concentrate shall be listed. The concentrate used in a foam system shall be acceptable for use on the specific flammable or combustible liquid to be protected. Some concentrates are suitable for use both on hydrocarbon fuels and on water-miscible or polar fuels and solvents. The limitations of the listing and the manufacturer’s specifications shall be followed.

2-3.1.1 Foam concentrates for protection of hydrocarbon fuels shall be one of the following types:

(a) Protein

(b) Fluoroprotein

(c) Aqueous film-forming foam (AFFF)

(d) Film-forming fluoroprotein (FFFP)

(e) Alcohol-resistant

(f) Others listed for this purpose

2-3.1.2 Water-miscible and polar flammable or combustible liquids shall be protected by alcohol-resistant concentrates listed for this purpose.

2-3.2 Concentrate Storage.

2-3.2.1 Storage Facilities. Foam concentrates and equipment shall be stored in an accessible location not exposed to the hazard they protect. If housed, they shall be in a noncombustible structure. For outdoor nonautomatic systems, the authority having jurisdiction can permit the storage of foam concentrate in a location off premises where these supplies are available at all times. Adequate loading and transportation facilities shall be ensured. Off-premises supplies shall be of the proper type for use in the systems of the given installation. At the time of a fire, these off-premises supplies shall be accumulated in sufficient quantities, before placing the equipment in operation, to ensure uninterrupted foam production at the design rate for the required period of time.

2-3.2.2* Quantity. The amount of concentrate shall be at least sufficient for the largest single hazard protected or group of hazards that are to be protected simultaneously.

2-3.2.3 Foam Concentrate Storage Tanks. Bulk liquid storage tanks shall be fabricated from or be lined with materials compatible with the concentrate.

2-3.2.4 Storage Conditions. In order to ensure the correct operation of any foam-producing system, the chemical and physical characteristics of the materials comprising the system shall be taken into consideration in design. Since such systems might or might not be operated for long periods after installation, the choice of proper storage conditions and maintenance methods largely determines the reliability and the degree of excellence of system operation when they are put into service.

2-3.2.4.1* Foam concentrates are subject to freezing and to deterioration from prolonged storage at high temperatures and shall be stored within the listed temperature limitations. They might be stored in the containers in which they are transported or might be transferred into large bulk storage tanks, depending on the requirements of the system. The location of stored containers requires special consideration to protect against exterior deterioration due to rusting or other causes. Bulk storage containers also require special design consideration to minimize the liquid surface in contact with air. Clear markings shall be provided on storage vessels to identify the type of concentrate and its intended concentration in solution.

2-3.2.5 Foam Concentrate Supply.

2-3.2.5.1 Foam Concentrate Consumption Rates. The consumption rates shall be based on the percentage concentrate used in the system design (e.g., 3 percent or 6 percent or other, if so listed or approved by the authority having jurisdiction).

2-3.2.5.2 Reserve Supply of Foam Concentrate. There shall be a readily available reserve supply of foam concentrate sufficient to meet design requirements in order to put the system back into service after operation. This supply can be in separate tanks or compartments, in drums or cans on the premises, or available from an approved outside source within 24 hours.

2-3.2.6 Auxiliary Supplies. Other equipment that might be necessary to recommission the system, such as bottles of nitrogen or carbon dioxide for premix systems, also shall be readily available.

2-4 Concentrate Compatibility.

2-4.1 Compatibility of Foam Concentrates. Different types and brands of concentrates and solutions might be incompatible and shall not be mixed in storage. Foams generated separately from protein, fluoroprotein, FFFP, and AFFF concentrates can be applied to a fire in sequence or simultaneously.

2-4.2 Foam Compatibility with Dry Chemical Agents. Some expanded foam might not be compatible with all dry chemical agents. The manufacturers of the dry chemical and foam concentrate to be used in the system shall confirm that their products are mutually compatible. Where used, limitations imposed on either of the agents alone shall be applied.

2-5 Foam Proportioning. The method of foam proportioning shall conform to one of the following:

(a) Foam nozzle eductor

(b) In-line eductor

(c) Pressure proportioners

(d) Around-the-pump proportioners

(e) Direct pumping proportioners

(f) Metered proportioning

(g) Balanced pressure proportioners

2-6* Foam Concentrate Pumps.

2-6.1 The design and materials of construction for foam concentrate pumps shall be suitable for use with the type of foam concentrate used in the system. Special attention shall be paid to the type of seal or packing used.

2-6.1.1 Where pumps utilizing cast or ductile iron components are used, the pumps shall be left flooded with concentrate to minimize corrosion, foaming, or sticking.

2-6.2 Foam concentrate pumps shall have adequate capacities to meet the maximum system demand. To ensure positive injection of concentrates, the discharge pressure ratings of pumps at the design discharge capacity shall be in excess of the maximum water pressure available under any condition at the point of concentration injection.

2-7 Piping.

2-7.1 Pipe Materials. Pipe within the hazard area shall be of steel or other alloy suitable for the pressure and temperature involved. Steel pipe shall not be less than standard weight (Schedule 40 through nominal 12-in. diameter). Steel pipe shall conform to ASTM A 135, Rev A-89, *Standard Specification for Electric Resistance-Welded Pipe,* A 53, Rev B-90, *Standard Specification for Pipe Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless,* or A 795, *Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use.* Pipe outside the hazard area shall conform to the materials allowed by NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.* Where exposed to corrosive influences, the piping shall be corrosion resistant or protected against corrosion.

Exception: Lightweight pipe [Schedule 10 in nominal sizes through 5 in.; 0.134-in. (3.40-mm) wall thickness for 6 in.; and 0.188-in. (4.78-mm) wall thickness for 8 in. and 10 in.] shall be permitted to be used in areas where fire exposure is improbable. Selection of pipe wall thickness shall anticipate internal pressure, internal and external pipe wall corrosion, and mechanical bending requirements.

2-7.1.1 Foam System Piping. Galvanized pipe shall be used for normally noncorrosive atmospheres. Corrosive atmospheres might require other coatings. Pipe carrying foam concentrate shall not be galvanized. Piping in constant contact with foam concentrates shall be constructed of material compatible with and not affected by the concentrate. Piping in constant contact with foam concentrate shall not have a detrimental effect on the foam concentrate.

2-7.1.1.1 For the purpose of computing friction loss in foam solution piping, the following *C*-values shall be used for the Hazen-Williams formula:

Black steel or unlined cast iron pipe — 100
Galvanized steel pipe — 120
Asbestos-cement or cement-lined cast iron pipe — 140

2-7.2 Fittings. All pipe fittings shall be in accordance with ANSI B16.1, *Cast Iron Pipe Flanges and Flanged Fittings;* B16.3, *Malleable Iron Threaded Fittings;* B16.4, *Gray Iron Threaded Fittings;* B16.5, *Pipe Flanges and Flanged Fittings;* B16.9, *Factory-Made Wrought Steel Buttwelding Fittings;* B16.11, *Forged Fittings, Socket-Welding and Threaded;* B16.25, *Buttwelding Ends;* or ASTM A 234, *Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures.* Fittings shall not be less than standard weight. Cast iron fittings shall not be used where dry sections of piping are exposed to possible fire or where fittings are subject to stress in self-supporting systems.

2-7.2.1 Rubber or elastomeric-gasketed fittings shall not be used in fire-exposed areas unless the foam system is automatically actuated.

2-7.2.2 Galvanized fittings shall be used for normally noncorrosive atmospheres. Corrosive atmospheres might require other coatings. Fittings carrying foam concentrate shall not be galvanized.

2-7.3 Joining of Pipes and Fittings. Pipe threading shall be in conformance with ANSI B1.20.1, *Pipe Threads.* Dimensions of cut- and roll-grooves and outside diameters of piping materials shall conform to the manufacturers' recommendations and the approval laboratories' certifications.

2-7.3.1* Welding practices shall conform to the requirements of AWS D10.9, *Standard for the Qualification of Welding Procedures and Welders for Piping and Tubing.* Special care shall be taken to ensure that the openings are fully cut out and that no obstructions remain in the waterway.

2-7.3.2 Care shall be taken to ensure that no galvanic corrosion can occur between piping and fittings.

2-7.4 Strainers. Where solids of sufficient size might be present to obstruct openings in foam equipment, approved strainers shall be used. The ratio of the strainer's open basket area to its inlet pipe area shall be at least 10:1.

2-7.5* Valves. All valves for water and foam solution lines shall be of the indicator type, such as OS&Y or post indicator. Valve specifications normal for water use shall be permitted outside the hazard or diked area. Inside the hazard or diked area, automatic control valves and shutoff valves shall be of steel or other alloy capable of withstanding exposure to expected fire temperatures.

2-7.5.1 All valves required for automatic foam systems shall be supervised in their normal operating position by one of the following methods:

(a) Electrical, in accordance with NFPA 72, *National Fire Alarm Code®*

(b) Locked

(c) Sealed

2-8 System Types. There are four basic types of systems:

(a) Fixed

(b) Semifixed

(c) Mobile

(d) Portable

2-8.1 Fixed Systems. These systems are complete installations in which foam is piped from a central foam station, discharging through fixed delivery outlets to the hazard to be protected. Any required pumps are permanently installed.

2-8.2 Semifixed Systems. These systems are the type in which the hazard is equipped with fixed discharge outlets connected to piping that terminates at a safe distance. The fixed piping installation might or might not include a foam maker. Necessary foam-producing materials are transported to the scene after the fire starts and are connected to the piping.

2-8.3 Mobile Systems. These systems include any type of foam-producing unit that is mounted on wheels and that is self-propelled or towed by a vehicle. These units can be connected to a suitable water supply or can utilize a premixed foam solution. (For mobile systems, see NFPA 11C, *Standard for Mobile Foam Apparatus.*)

2-8.4 Portable Systems. These systems are the type in which the foam-producing equipment and materials, hose, and so forth, are transported by hand.

2-9 Operation and Control of Systems.

2-9.1 Methods of Actuation. Systems can be actuated automatically or manually. All systems shall have provisions for manual actuation.

2-9.2 Automatically Actuated Systems.

2-9.2.1 An automatic system is one that is activated by automatic detection equipment.

2-9.2.2 Operation shall be controlled by listed or approved mechanical, electrical, hydraulic, or pneumatic means. Where operation is automatic, an adequate and reliable source of energy shall be used. The need for an alternate power supply shall be determined by the authority having jurisdiction.

2-9.2.3 Automatic detection equipment — whether pneumatic, hydraulic, or electric — shall be provided with supervision arranged so that failure of equipment or loss of supervising air pressure or loss of electric energy results in positive notification of the abnormal condition. (See applicable sections of NFPA 72, *National Fire Alarm Code.*)

Exception: Small systems for localized hazards shall be permitted to be unsupervised, subject to approval of the authority having jurisdiction.

2-9.2.4 Electric automatic detection equipment and any auxiliary electric equipment, if in hazardous areas, shall be designed expressly for use in such areas. (See NFPA 70, *National Electrical Code®*, Article 500 and other articles in Chapter 5.)

2-9.2.5 In some cases, it shall be permitted to arrange to shut off automatically after a predetermined operating time. This feature shall be subject to the approval of the authority having jurisdiction. Where automatic shutdown is required, an alarm condition shall remain until manually reset.

2-9.2.6 The detection system shall activate a local alarm as well as an alarm at a constantly attended location. These alarms also shall be actuated when the system is operated manually.

2-9.3 Manually Actuated Systems. Controls for manually actuated systems shall be located in an accessible place sufficiently removed from the hazard zone to permit them to be operated safely in an emergency, yet close enough to ensure operator knowledge of fire conditions. The location and purposes of the controls shall be indicated plainly and shall be related to the operating instructions.

2-9.4 Equipment. All operating devices shall be suitable for the service conditions they encounter. They shall not be readily rendered inoperative, or be susceptible to inadvertent operation, by environmental factors such as high or low temperature, atmospheric humidity or pollution, or marine conditions. Such systems shall have means for manual actuation.

Chapter 3 System Design

3-1* Types of Hazards. This chapter covers design information for the use of foam to protect outdoor storage tanks, interior flammable liquid hazards, loading racks, diked areas, and nondiked spill areas.

3-2* Outdoor Fixed-Roof (Cone) Tanks. Within the scope of this standard, fixed-roof (cone) tanks are defined as vertical cylindrical tanks with a fixed-roof designed as a conical section, and they comply with the requirements set forth in NFPA 30, *Flammable and Combustible Liquids Code*. Typically, these tanks have a weak seam at the junction of the vertical side and roof. In the event of an internal explosion, the seam usually parts; the roof blows off, leaving the shell intact to retain the tank contents. The resulting fire involves the entire exposed surface of the product.

3-2.1 Methods of Protection. The following methods for protecting exterior fixed-roof tanks are included within this section:

(a) Foam monitors and handlines

(b) Surface application with fixed foam discharge outlets

(c) Subsurface application

(d) Semisubsurface injection methods

This list of methods shall not be considered to be in any order of preference.

3-2.1.1 Supplementary Protection. In addition to the primary means of protection, there shall be provisions for supplementary protection in accordance with the requirements found in Section 3-9.

3-2.1.2 Basis of Design. System design shall be based on protecting the tank requiring the largest foam solution flow, including supplementary hose streams.

3-2.1.3* Limitations. The requirements provided in this section are based on extrapolations of test experience and appropriate listings and reflect the limitations known to date.

Foam can fail to seal against the tank shell as a result of prolonged free burning prior to agent discharge. If adequate water supplies are available, cooling of the tank shell is recommended.

Fixed outlets shall not be used to protect horizontal or pressure tanks.

3-2.2 Design Criteria for Foam Monitors and Handlines.

3-2.2.1 Limitations. Monitor nozzles shall not be considered as the primary means of protection for fixed-roof tanks over 60 ft (18 m) in diameter. Foam handlines shall not be considered as the primary means of protection for fixed-roof tanks over 30 ft (9 m) in diameter or those over 20 ft (6 m) in height.

3-2.2.2 Foam Application Rates. The specified minimum delivery rate for primary protection is based on the assumption that all the foam reaches the area being protected. In determining actual solution flow requirements, consideration shall be given to potential foam losses from wind and other factors.

3-2.2.3* The design parameters for the use of monitors and handline nozzles to protect tanks containing hydrocarbons shall be in accordance with Table 3-2.2.3.

3-2.2.4* Tanks Containing Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams. Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to regular (nonalcohol-resistant) foams require the use of alcohol-resistant foams. In general, alcohol-resistant foams can be effectively applied through foam monitor or foam hose streams to spill fires of these liquids when the liquid depth does not exceed 1 in. (25.4 mm).

Table 3-2.2.3 Foam Handline and Monitor Protection for Fixed-Roof Storage Tanks Containing Hydrocarbons

Hydrocarbons Type	Minimum Application Rate (gpm/ft^2)	Minimum Application Rate (L/min·m^2)	Minimum Discharge Time (min)
Flash point between 100°F and 140°F (37.8°C and 93.3°C)	0.16	6.5	50
Flash point below 100°F (37.8°C) or liquids heated above their flash points	0.16	6.5	65
Crude petroleum	0.16	6.5	65

NOTE 1: Included in this table are gasohols and unleaded gasolines containing no more than 10 percent oxygenated additives by volume. Where oxygenated additives content exceeds 10 percent by volume, protection is normally in accordance with 3-2.2.4. Certain nonalcohol-resistant foams might be suitable for use with fuels containing oxygenated additives of more than 10 percent by volume. The manufacturer should be consulted for specific listings or approvals.

NOTE 2: Flammable liquids having a boiling point of less than 100°F (37.8°C) might require higher rates of application. Suitable rates of application should be determined by test. Flammable liquids with a wide range of boiling points might develop a heat layer after prolonged burning and then can require application rates of 0.2 gpm/ft^2 (8.1 L/min·m^2) or more.

NOTE 3: Care should be taken in applying portable foam streams to high-viscosity materials heated above 200°F (93.3°C). Good judgment should be used in applying foam to tanks containing hot oils, burning asphalts, or burning liquids that have a boiling point above the boiling point of water. Although the comparatively low water content of foams can beneficially cool such fuels at a slow rate, it can also cause violent frothing and "slop over" of the tank's contents.

For liquids of greater depth, monitor and foam hose streams shall be limited for use with special alcohol-resistant foams listed or approved, or both, for the purpose. If application results in foam submergence, the performance of alcohol-resistant foams usually deteriorates significantly, particularly where there is a substantial depth of fuel. The degree of performance deterioration depends on the degree of water solubility of the fuel (i.e., the more soluble, the greater the deterioration).

In all cases, the manufacturer of the foam concentrate and the foam-making equipment shall be consulted as to limitations and for recommendations based on listings or specific fire tests.

3-2.2.5 Design Parameters. Where monitors and handline nozzles are used to protect tanks containing flammable and combustible liquids requiring alcohol-resistant foams, the operation time shall be 65 minutes at listed application rates, unless the foam manufacturer has established, by fire test, that a shorter time can be permitted.

3-2.3 Design Criteria Surface Application with Fixed Foam Discharge Outlets.

3-2.3.1 Fixed Foam Discharge Outlets. For this application, discharge outlets are commonly called foam chambers. Most foam chambers are of a Type II discharge outlet design, since they are normally suitable for use with modern foams. For the protection of a flammable liquid contained in a vertical fixed-roof (cone) atmospheric storage tank, discharge outlets shall be attached to the tank. Where two or more discharge outlets are required, the outlets shall be spaced equally around the tank periphery, and each outlet shall be sized to deliver foam at approximately the same rate. Fixed foam discharge outlets shall be attached securely at the top of the shell and shall be located or connected to preclude the possibility of the tank contents overflowing into the foam lines. They shall be attached securely so that displacement of the roof is not likely to subject them to serious damage. Fixed foam discharge outlets shall be provided with an effective and durable seal, frangible under low pressure, to prevent entrance of vapors into foam outlets and pipelines. Fixed foam discharge outlets shall be provided with suitable inspection means to permit proper maintenance and for inspection and replacement of vapor seals.

3-2.3.2 Design Criteria for Tanks Containing Hydrocarbons.

3-2.3.2.1* Fixed-roof (cone) tanks shall be provided with approved fixed foam discharge outlets as indicated in Table 3-2.3.2.1.

3-2.3.2.2* Minimum Discharge Times and Application Rates. When fixed foam discharge outlets are used for fixed-roof (cone) tanks containing hydrocarbons, the minimum discharge times and application rates shall be in accordance with Table 3-2.3.2.2.

3-2.3.2.2.1 If the apparatus available has a delivery rate higher than 0.1 gpm/ft^2 (4.1 L/min·m^2), a proportionate reduction in the time figure can be made, except that the time shall not be less than 70 percent of the minimum discharge times shown.

3-2.3.3* Design Criteria for Tanks Containing Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams. Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to nonalcohol-resistant foams require the use of alcohol-resistant foams. Systems using these foams require special engineering consideration. In all cases, the manufacturers of the foam concentrate and the foam-making equipment shall be consulted as to limitations and for recommendations based on listings or specific fire tests.

Table 3-2.3.2.1 Number of Fixed Foam Discharge Outlets for Fixed-Roof Tanks Containing Hydrocarbons or Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams

Tank Diameter (or equivalent area)		Minimum Number of Discharge Outlets
(ft)	(m)	
Up to 80	Up to 24	1
Over 80 to 120	Over 24 to 36	2
Over 120 to 140	Over 36 to 42	3
Over 140 to 160	Over 42 to 48	4
Over 160 to 180	Over 48 to 54	5
Over 180 to 200	Over 54 to 60	6

3-2.3.3.1 Fixed-roof (cone) tanks shall be provided with approved fixed foam discharge outlets as indicated in Table 3-2.3.2.1.

3-2.3.3.2 Minimum Discharge Times and Application Rates. Minimum discharge times and application rates for fixed-roof (cone) tanks containing flammable and combustible liquids requiring alcohol-resistant foams shall be in accordance with Table 3-2.3.3.2.

3-2.4 Subsurface Application Design Criteria.

3-2.4.1* Subsurface foam injection systems are suitable for protection of liquid hydrocarbons in vertical fixed-roof atmospheric storage tanks. Subsurface injection systems shall not be used for protection of Class IA hydrocarbon liquids or for the protection of alcohols, esters, ketones, aldehydes, anhydrides, or other products requiring the use of alcohol-resistant foams. Foam concentrates and equipment for subsurface injection shall be listed for this purpose. Fluoroprotein foam, AFFF, and FFFP for subsurface injection shall have expansion ratios between 2 and 4.

3-2.4.2* Foam Discharge Outlets. The discharge outlet into the tank can be the open end of a foam delivery line or product line. Outlets shall be sized so that foam generator discharge pressure and foam velocity limitations are not exceeded. The foam velocity at the point of discharge into the tank contents shall not exceed 10 ft/sec (3 m/sec) for Class IB liquids or 20 ft/sec (6 m/sec) for other classes of liquids unless actual tests prove higher velocities are satisfactory. Where two or more outlets are required, they shall be located so that the foam travel on the surface can not exceed 100 ft (30 m). Each outlet shall be sized to deliver foam at approximately the same rate. For even foam distribution, outlets can be shell connections or can be fed through a pipe manifold within the tank from a single shell connection. Rather than installing additional tank nozzles, shell connections can be made in manway covers. Tanks shall be provided with subsurface foam discharge outlets as shown in Table 3-2.4.2.

Table 3-2.3.2.2 Minimum Discharge Times and Application Rate for Type I and Type II Fixed Foam Discharge Outlets on Fixed-Roof (Cone) Storage Tanks Containing Hydrocarbons

Hydrocarbon Type	Minimum Application Rate (gpm/ft²)	Minimum Application Rate (L/min·m²)	Minimum Discharge Time (min) Type I Foam Discharge Outlet	Minimum Discharge Time (min) Type II Foam Discharge Outlet
Flash point between 100°F and 140°F (37.8°C and 93.3°C)	0.10	4.1	20	30
Flash point below 100°F (37.8°C) or liquids heated above their flash points	0.10	4.1	30	55
Crude petroleum	0.10	4.1	30	55

NOTE 1: Included in this table are gasohols and unleaded gasolines containing no more than 10 percent oxygenated additives by volume. Where oxygenated additives content exceeds 10 percent by volume, protection is normally in accordance with 3-2.3.3. Certain nonalcohol-resistant foams might be suitable for use with fuels containing oxygenated additives of more than 10 percent by volume. The manufacturer shall be consulted for specific listings or approvals.

NOTE 2: Flammable liquids having a boiling point of less than 100°F (37.8°C) might require higher rates of application. Suitable rates of application should be determined by test.

NOTE 3: For high-viscosity liquids heated above 200°F (93.3°C), lower initial rates of application might be desirable to minimize frothing and expulsion of the stored liquid. Good judgment should be used in applying foams to tanks containing hot oils, burning asphalts, or burning liquids that have boiling points above the boiling point of water. Although the comparatively low water content of foams can beneficially cool such liquids at a slow rate, it can also cause violent frothing and "slop over" of the tank's contents.

Table 3-2.3.3.2 Minimum Application Rate and Discharge Times for Fixed-Roof (Cone) Tanks Containing Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams

Application Rate for Specific Product Stored	Minimum Discharge Time (min) Type I Foam Discharge Outlet	Minimum Discharge Time (min) Type II Foam DischargeOutlet
Consult manufacturer for listings on specific products	30	55

Note: Most currently manufactured alcohol-resistant foams are suitable for use with Type II fixed foam discharge outlets. However, some older alcohol-resistant foams require gentle surface application by Type I fixed foam discharge outlets. Consult manufacturers for listings on specific products.

3-2.4.2.1* Foam Discharge Outlet Elevation. Foam discharge outlets shall be located so as not to discharge into a water bottom. This shall be accomplished by having the outlets located at least 1 ft (0.3 m) above the highest water level to prevent destruction of the foam.

3-2.4.2.2* Subsurface Injection Back-Pressure Limitations. The sizes and lengths of discharge pipe or lines used beyond the foam maker and the anticipated maximum depth of the fuel to be protected shall be such that the back pressure is within the range of pressures under which the device has been tested and listed by testing laboratories.

3-2.4.3 Minimum Discharge Times and Application Rates. The minimum discharge times and application rates for subsurface application on fixed-roof storage tanks shall be in accordance with Table 3-2.4.3.

3-2.4.3.1* Liquid hydrocarbons that contain foam-destructive products might require higher application rates. Some foams might fail to extinguish fires in gasolines containing oxygenates where using subsurface discharge at the usually required rate. In such cases, the manufacturer of the foam concentrate shall be consulted for recommendations based on listings and/or approvals.

3-2.5* Semisubsurface Systems. All equipment used in such systems shall be listed or approved for this purpose.

3-3 Outdoor Open-Top Floating Roof Tanks. Within the scope of this standard, open-top floating roof tanks are defined as vertical cylindrical tanks without fixed-roofs that have double-deck or pontoon-type floating roofs and are constructed in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*. The seal can be a mechanical shoe seal or tube seal. The tube seal can be equipped with a metal weather shield. Secondary seals of combustible or noncombustible materials can also be installed. *[See Figures 3-3(a) through (d).]*

Tanks equipped with the following floating roof types are not covered in Section 3-3:

(a) Roofs made from floating diaphragms
(b) Roofs made from plastic blankets
(c) Roofs made from plastic or other flotation material, even if encapsulated in metal or fiberglass
(d) Roofs that rely on flotation device closures that can be easily submerged if damaged
(e) Pan roofs

Systems for tanks so equipped shall be designed in accordance with 3-4.1.1.

Table 3-2.4.2 Minimum Number of Subsurface Foam Discharge Outlets for Fixed-Roof Tanks Containing Hydrocarbons

Tank Diameter		Minimum Number of Discharge Outlets	
(ft)	(m)	Flash Point Below 100°F (37.8°C)	Flash Point 100°F (37.8°C) or Higher
Up to 80	Up to 24	1	1
Over 80 to 120	Over 24 to 36	2	1
Over 120 to 140	Over 36 to 42	3	2
Over 140 to 160	Over 42 to 48	4	2
Over 160 to 180	Over 48 to 54	5	2
Over 180 to 200	Over 54 to 60	6	3
Over 200	Over 60	6	3
		Plus 1 outlet for each additional 5000 ft^2 (465 m^2)	Plus 1 outlet for each additional 7500 ft^2 (697 m^2)

NOTE 1: Liquids with flash points below 73°F (22.8°C), combined with boiling points below 100°F (37.8°C), require special consideration.

NOTE 2: Table 3-2.4.2 is based on extrapolation of fire test data on 25-ft (7.5-m), 93-ft (27.9-m), and 115-ft (34.5-m) diameter tanks containing gasoline, crude oil, and hexane, respectively.

NOTE 3: The most viscous fuel that has been extinguished by subsurface injection where stored at ambient conditions [60°F (15.6°C)] had a viscosity of 2000 ssu (440 centistokes) and a pour point of 15°F (–9.4°C). Subsurface injection of foam generally is not recommended for fuels that have a viscosity greater that 2000 ssu (440 centistokes) at their minimum anticipated storage temperature.

NOTE 4: In addition to the control provided by the smothering effect of the foam and the cooling effect of the water in the foam that reaches the surface, fire control and extinguishment can be enhanced further by the rolling of cool product to the surface.

Table 3-2.4.3 Minimum Discharge Times and Application Rates for Subsurface Application on Fixed-Roof Storage Tanks

Hydrocarbon Type	Minimum Discharge Time (min)	Minimum Application Rate	
		(gpm/ft^2)	(L/min·m^2)
Flash point between 100°F and 140°F (37.8°C and 93.3°C)	30	0.1	4.1
Flash point below 100°F (37.8°C) or liquids heated above their flash points	55	0.1	4.1
Crude petroleum	55	0.1	4.1

NOTE 1: The maximum application rate shall be 0.20 gpm/ft^2 (8.1 L/min·m^2).

NOTE 2: For high-viscosity liquids heated above 200°F (93.3°C), lower initial rates of application might be desirable to minimize frothing and expulsion of the stored liquid. Good judgment should be used in applying foams to tanks containing hot oils, burning asphalts, or burning liquids that are heated above the boiling point of water. Although the comparatively low water content of foams can beneficially cool such liquids at a slow rate, it can also cause violent frothing and "slop over" of the tank's contents.

3-3.1* Types of Fires Anticipated. Open-top floating roof tanks can experience two distinct types of fires: a seal fire or a full surface area fire (as a result of the floating roof sinking). Experience indicates that the most frequent type of fire involves only the seal of the floating roof tank. Prior to selecting the method of protection, the type of fire that will serve as the basis for design shall be defined. *(See NFPA 30, Flammable and Combustible Liquids Code, for fire protection requirements.)*

3-3.1.1 Subsurface and semisubsurface injection shall not be used for protection of open-top or covered floating roof tanks because of the possibility of improper distribution of foam at the fuel surface.

3-3.1.2 Seal Area Protection. The foam protection facilities for an open-top floating roof tank seal area shall be based on 3-3.2 through 3-3.5.

3-3.2 Methods of Seal Fire Protection. The following methods for fire protection of seals in open-top floating roof tanks are described in 3-3.3 through 3-3.5:

(a) Fixed discharge outlets

(b) Foam handlines

(c) Foam monitors

3-3.2.1 Supplementary Protection. In addition to the primary means of protection, there shall be provisions for supplementary protection in accordance with the requirements of Section 3-9.

3-3.2.2 Basis of Design. System design shall be based on protecting the tank requiring the largest foam solution flow, including supplementary hose streams.

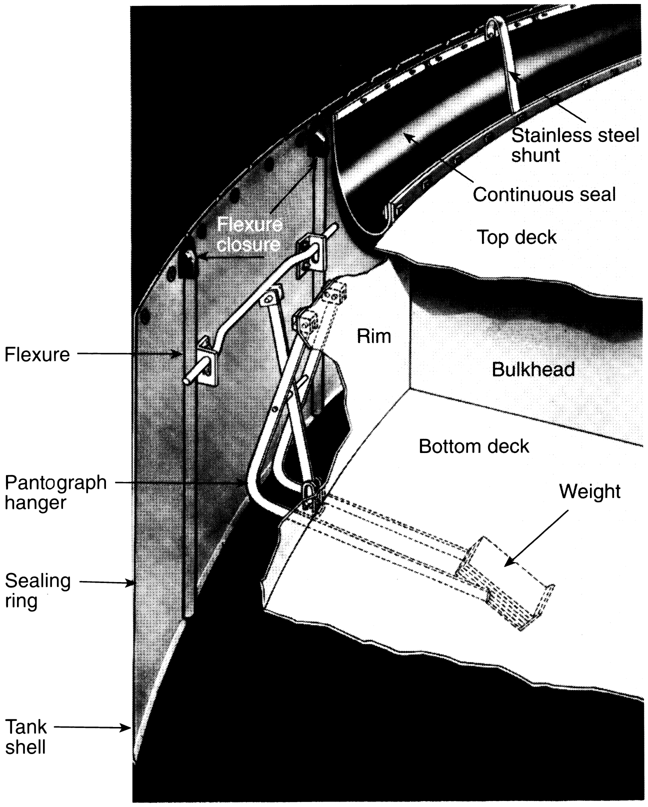


Figure 3-3(a) Pantograph-type seal open-top floating roof tank.

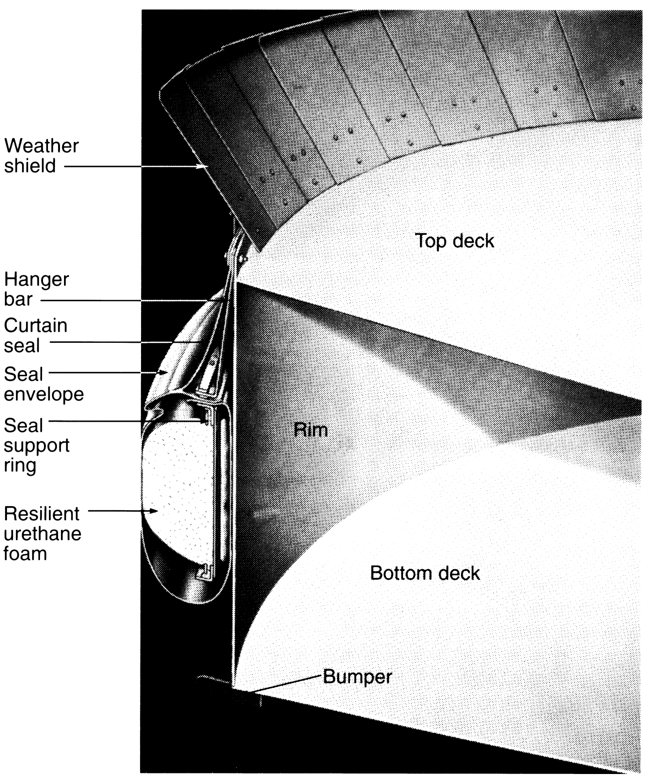


Figure 3-3(b) Tube seal open-top floating roof tank.

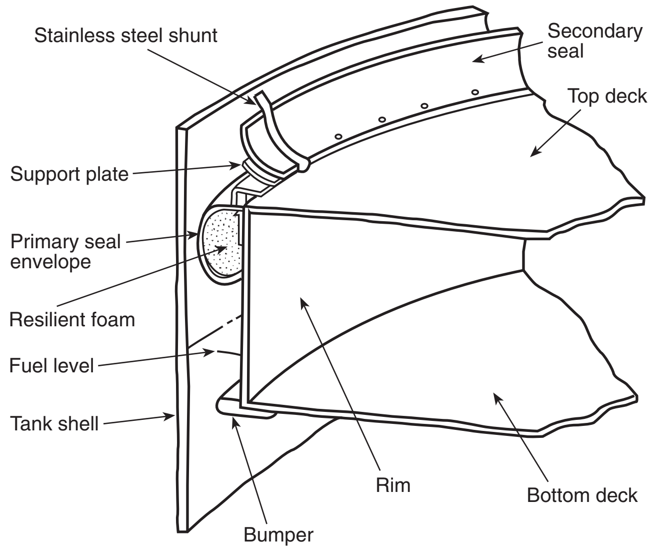


Figure 3-3(c) Double seal system for floating roofs.

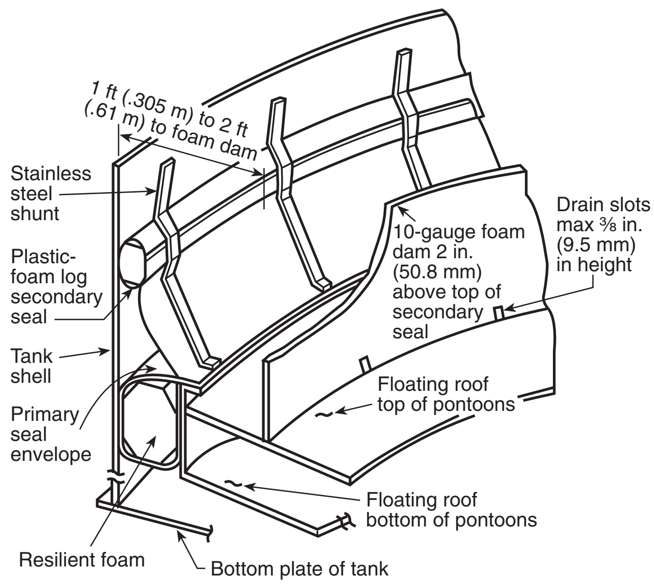


Figure 3-3(d) Double seal system for floating roofs using a plastic-foam log (secondary seal).

3-3.2.3 Limitations. The requirements given in this section are based on extrapolations of test experience and appropriate listings and reflect the limitations known to date.

Foam can fail to seal against the tank shell as a result of prolonged free burning prior to agent discharge. If adequate water supplies are available, cooling of the tank shell is recommended.

3-3.3 Fixed Discharge Outlets Design Criteria for Seal Area Protection. Application of foam from fixed discharge outlets can be achieved by either of the following two methods:

(a) The first method discharges foam above the mechanical shoe seal, a metal weather shield, or a secondary seal.

(b) The second method discharges foam below a mechanical shoe seal directly onto the flammable liquid, behind a metal weather shield directly onto the tube seal envelope, or beneath a secondary seal onto the primary seal.

3-3.3.1 Top-of-Seal Method with Foam Dam. Fixed foam discharge outlets located above a mechanical shoe seal, above a tube seal weather shield, or above a secondary seal shall be used in conjunction with a foam dam. See 3-3.3.3 for foam dam design criteria. There are two acceptable arrangements when utilizing fixed foam discharge outlets:

(a) Fixed foam discharge outlets (normally Type II) mounted above the top of the tank shell

(b) Fixed foam discharge outlets mounted on the periphery of the floating roof

[See Appendix Figures A-3-3.3.1.1(a) and (b).]

3-3.3.1.1* For this application, the fixed foam discharge outlets shall not be fitted with a frangible vapor seal device.

3-3.3.1.2 Top-of-Seal System Design. The design parameters for the application of fixed foam discharge outlets on top of the seal to protect open-top floating roof tanks shall be in accordance with Table 3-3.3.1.2. The requirements specified in the table apply to tanks containing hydrocarbons or flammable and combustible materials requiring alcohol-resistant foams. The required minimum application rates specified in Table 3-3.3.1.2 apply, unless listings for specific products require higher application rates where Type II fixed foam discharge outlets are used. *(See Figure 3-3.3.1.2.)*

NOTE: Both fixed foam (wall-mounted) and roof-mounted discharge outlets are shown for illustrative purposes. Although both methods are shown, only one is needed.

3-3.3.1.3 If the application rate is higher than the minimum rate specified in Table 3-3.3.1.2, the discharge time can be reduced proportionately, but not less than 70 percent of the minimum discharge times specified.

3-3.3.2 Below Primary Seal or Weather Shield Method. Fixed foam discharge outlets located below either a mechanical shoe seal, a metal weather shield, or a metal secondary seal shall use the designs that are illustrated in Figure 3-3.3.2.2.

3-3.3.2.1 A foam dam shall be installed if a tube seal is used and the top of the tube seal is less than 6 in. (152 mm) below the top of the pontoon. See 3-3.3.3 for foam dam design criteria.

3-3.3.2.2 Below-the-Seal or Weather Shield System. The design parameters for the application of fixed foam discharge outlets below the seal (or weather shield) to protect open-top floating roof tanks shall be in accordance with Table 3-3.3.2.2. The requirements given in the table apply to tanks containing hydrocarbons or flammable and combustible materials requiring alcohol-resistant foams. The required minimum application rates given in Table 3-3.3.2.2 apply unless listings for specific products require higher application rates when Type II fixed foam discharge outlets are used. *(See Figure 3-3.3.2.2.)*

3-3.3.2.3 Below-the-seal (or shield) application shall not be used with combustible secondary seals.

3-3.3.3 Foam Dam Design Criteria.

3-3.3.3.1 The foam dam shall be circular and constructed of at least No. 10 U.S. standard gauge thickness [0.134-in. (3.4-mm)] steel plate.

3-3.3.3.2 The foam dam shall be welded or otherwise securely fastened to the floating roof.

3-3.3.3.3 The foam dam shall be designed to retain foam at the seal area, at a sufficient depth to cover the seal area while causing the foam to flow laterally to the point of seal rupture. Dam height shall be at least 12 in. (305 mm). The dam shall extend at least 2 in. (51 mm) above a metal secondary seal or a combustible secondary seal using a plastic-foam log. Dam height shall be at least 2 in. (51 mm) higher than any burnout panels in metal secondary seals.

3-3.3.3.4 The foam dam shall be at least 1 ft (0.3 m), but not more than 2 ft (0.6 m), from the tank shell.

3-3.3.3.5 To allow drainage of rain water, the foam dam bottom shall be slotted on the basis of 0.04 in.^{2} of slot area per ft^2 of dammed area (278 mm^2 of slot area per m^2 of dammed area) restricting drain slots to a maximum $^3/_8$ in. (9.5 mm) in height. Excessive dam openings for drainage shall be avoided to prevent loss of foam through the drainage slots. *(See Figure 3-3.3.3.5.)*

3-3.4* Foam Handline Design Criteria for Seal Area Protection. Foam handlines can be used from the wind girder for extinguishment of seal fires in open-top floating roof tanks. Listed or approved equipment shall be used. *(See A-3-3.4 and Figure A-3-3.4 for a suggested system design.)*

3-3.5 Foam Monitor Design Criteria for Seal Area Protection. Monitors shall not be used as the primary means of floating roof seal fire extinguishment because of the difficulty of directing foam into the annular space and the possibility of sinking the roof.

Table 3-3.3.1.2 Top-of-Seal Fixed Foam Discharge Protection for Open-Top Floating Roof Tanks *(See Figure 3-3.3.1.2)*

Seal Type	Applicable Illustration Detail	Minimum Application Rate (gpm/ft^2)	Minimum Application Rate (L/min·m^2)	Minimum Discharge Time (min)	Maximum Spacing Between Discharge Outlets with 12-in. (305-mm) Foam Dam ft (m)	Maximum Spacing Between Discharge Outlets with 24-in. (610-mm) Foam Dam ft (m)
Mechanical shoe seal	A	0.3	12.2	20	40 (12.2)	80 (24.4)
Tube seal with metal weather shield	B	0.3	12.2	20	40 (12.2)	80 (24.4)
Fully or partly combustible secondary seal	C	0.3	12.2	20	40 (12.2)	80 (24.4)
All metal secondary seal	D	0.3	12.2	20	40 (12.2)	80 (24.4)

Note: Where the fixed foam discharge outlets are mounted above the top of the tank shell, a foam splashboard is necessary due to the effect of winds.

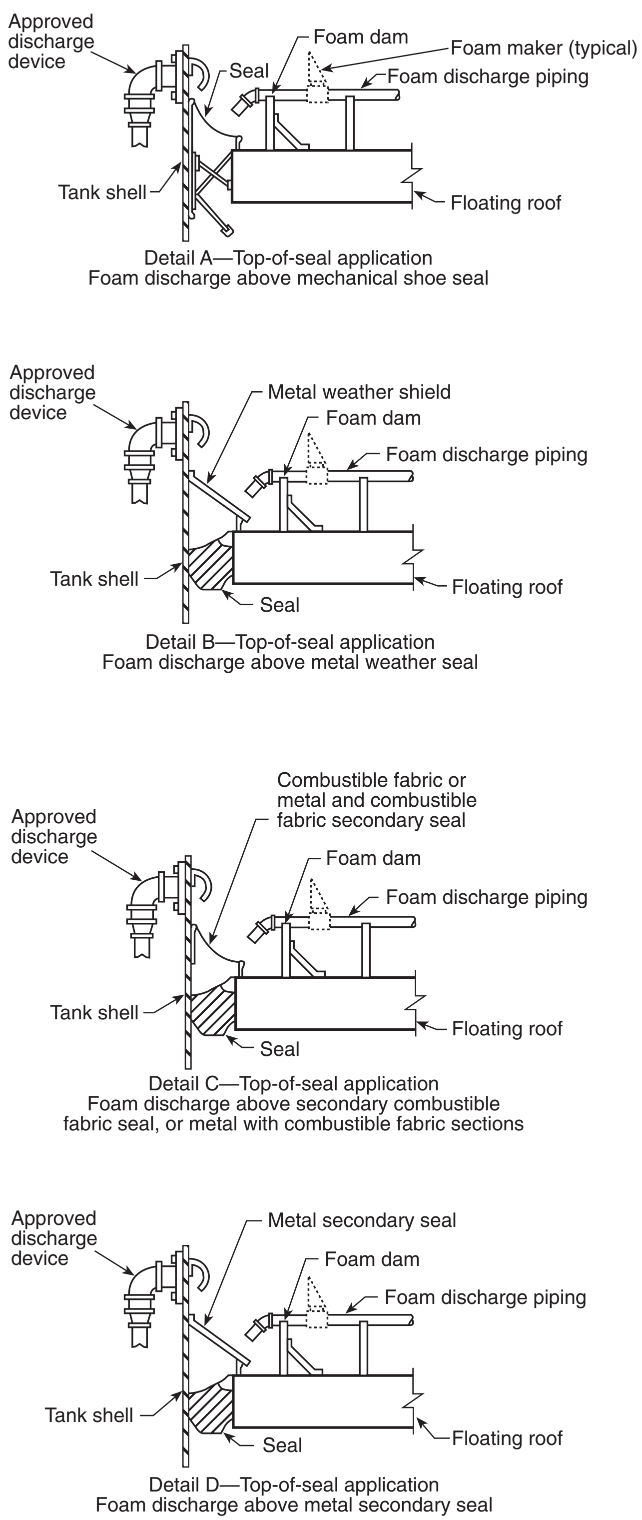


Figure 3-3.3.1.2 Typical foam system illustrations for top-of-seal fire protection.

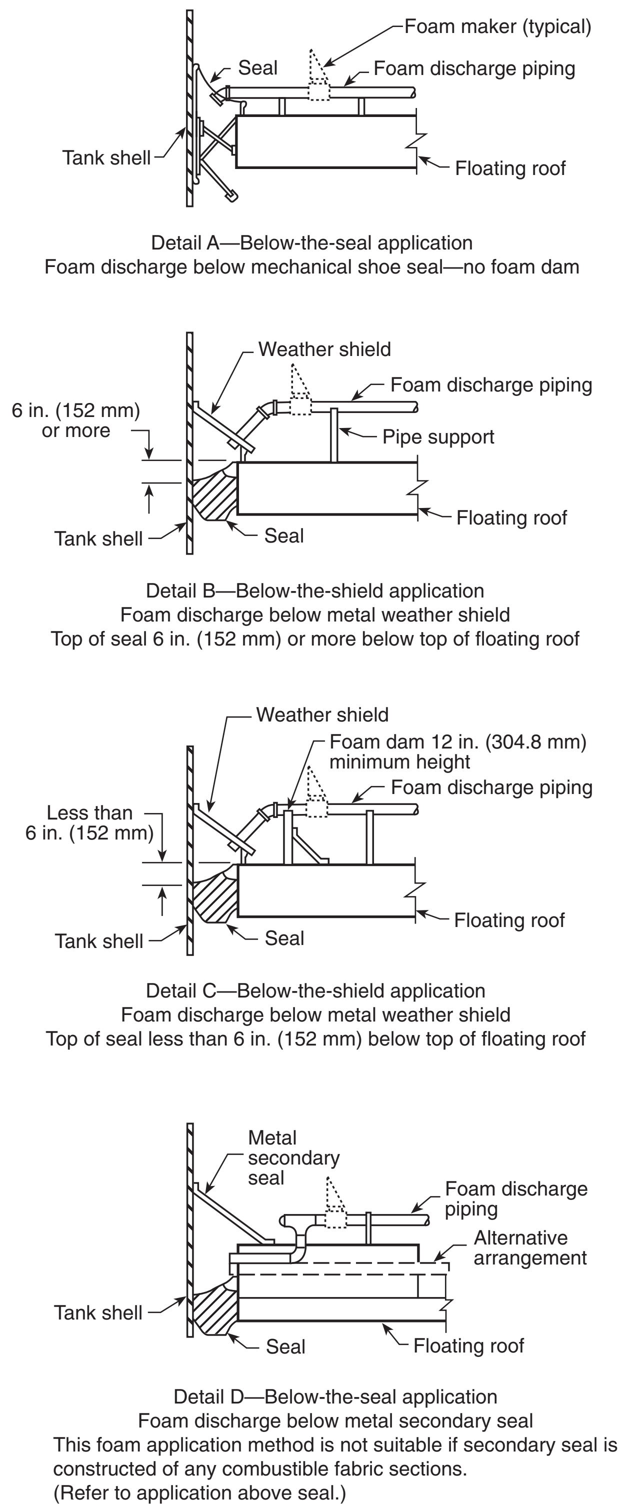


Figure 3-3.3.2.2 Typical foam system arrangement illustrations for below-the-seal (or shield) application.

Table 3-3.3.2.2 Below-the-Seal Fixed Foam Discharge Protection for Open-Top Floating Roof Tanks *(See Figure 3-3.3.2.2)*

Seal Type	Applicable Illustration Detail	Minimum Application Rate (gpm/ft²)	Minimum Application Rate (L/min·m²)	Minimum Discharge Time (min)	Maximum Spacing Between Discharge (Outlets)
Mechanical shoe seal	A	0.5	20.4	10	130 ft (39 m) — Foam dam not required
Tube seal with more than 6 in. (152 mm) between top of tube and top of pontoon	B	0.5	20.4	10	60 ft (18 m) — Foam dam not required
Tube seal with less than 6 in. (152 mm) between top of tube and top of pontoon	C	0.5	20.4	10	60 ft (18 m) — Foam dam required
Tube seal with foam discharge below metal secondary seal*	D	0.5	20.4	10	60 ft (18 m) — Foam dam not required

*A metal secondary seal is equivalent to a foam dam.

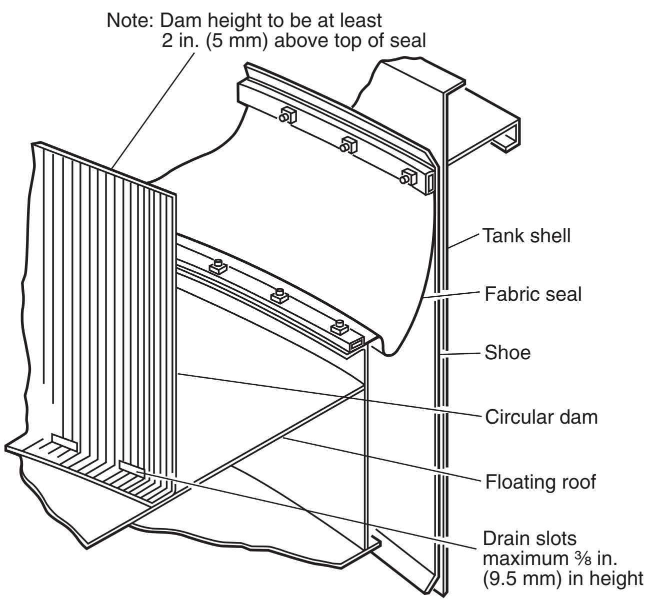


Figure 3-3.3.3.5 Typical foam dam for floating roof tank protection.

3-4 Outdoor Covered (Internal) Floating Roof Tanks. Within the scope of this standard, covered (internal) floating roof tanks are defined as vertical cylindrical tanks with a fixed metal roof (cone or geodesic dome) equipped with ventilation at the top and containing a metal double-deck or pontoon-type floating roof or a metal floating cover supported by liquidtight metal flotation devices. They are constructed in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code. (See Figure 3-4).*

Tanks equipped with the following floating roof types are not covered in Section 3-4:

(a) Roofs made from floating diaphragms

(b) Roofs made from plastic blankets

(c) Roofs made with plastic or other flotation material, even if encapsulated in metal or fiberglass

(d) Roofs that rely on flotation device closures that can be easily submerged if damaged

(e) Pan roofs

3-4.1 The following types of roof construction shall be considered suitable for seal area protection systems:

(a) Steel double deck

(b) Steel pontoon

(c) Full liquid surface contact, closed cell honeycomb, of metal construction conforming to API 650, *Welded Steel Tanks for Oil Storage,* Appendix H, "Internal Floating Roofs" requirements

All other types of roof construction shall require full surface protection.

3-4.1.1 Design for Full Surface Fire. Where the basis for design is a full surface fire, the covered (internal) floating roof tank shall be considered as equivalent to a fixed-roof (cone) tank of the same diameter for the purpose of foam system design. For a full surface fire, the foam facilities shall be designed in accordance with 3-2.3 and Section 3-9, except that separately valved laterals for each foam discharge shall not be required. For this application, fixed foam discharge outlets shall not be fitted with a frangible vapor seal device.

3-4.1.1.1 Subsurface and semisubsurface injection shall not be used because of the possibility of improper distribution of foam.

3-4.1.2 Design for Seal Area Fire. Where the basis for design is a seal fire, the covered (internal) floating roof tank shall be considered as equivalent to an open-top floating roof tank of the same diameter for the purpose of foam system design. For a seal fire, the foam discharge system shall be designed in accordance with the requirements specified in 3-3.3.1.2 utilizing fixed foam discharge outlets.

3-4.1.2.1 Supplementary Protection. In addition to the primary means of protection, there shall be provisions for supplementary protection in accordance with the requirements of Section 3-9.

3-4.1.2.2* Basis of Design. System design shall be based on protecting the tank requiring the largest solution flow, including supplementary hose streams.

If the application rate is higher than the minimum rate specified in Table 3-2.3.2.2, the discharge time shall be permitted to be reduced proportionately, but shall not be less than 70 percent of the minimum discharge times specified.

3-4.1.2.3 Limitations. The requirements given in this section are based on extrapolations of test experience and appropriate listings and reflect the limitations known to date.

Foam can fail to seal against the tank shell as a result of prolonged free burning prior to agent discharge. If adequate water supplies are available, cooling of the tank shell is recommended.

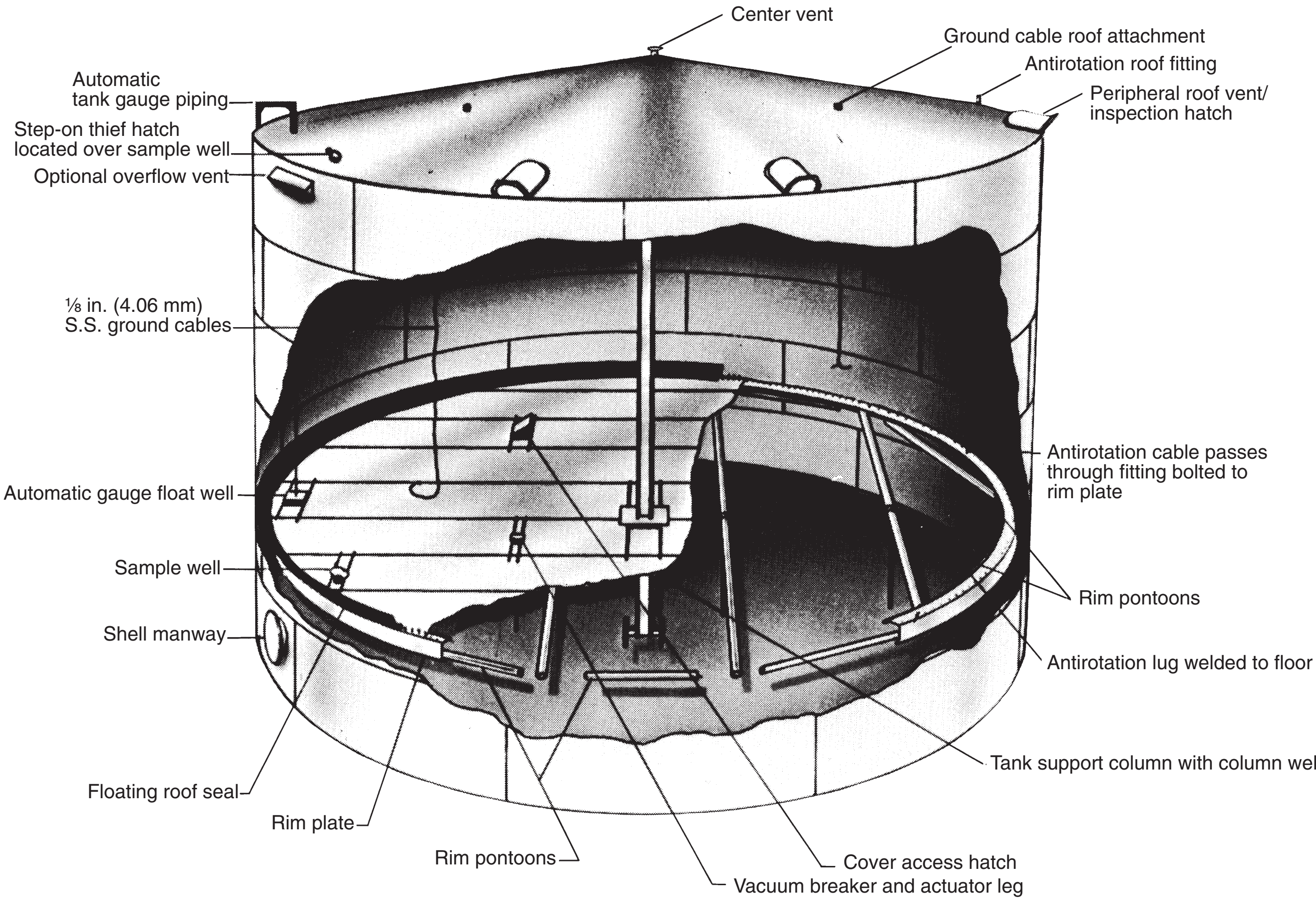


Figure 3-4 Typical covered floating roof tank.

3-5 Indoor Hazards. This section addresses foam fire-extinguishing systems, which are intended to protect indoor storage tanks that have liquid surface areas of 400 ft^2 (37.2 m^2) or greater. (For other types of indoor hazards, see the design criteria requirements of NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, and NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems.*)

3-5.1 Discharge Outlets. Tanks for storing liquid hydrocarbons shall be fitted with Type II, tank-mounted fixed foam discharge outlets as specified in Table 3-2.3.2.1.

3-5.2 Minimum Discharge Time and Application Rate. The minimum application rate for indoor hydrocarbon storage tanks shall be 0.16 gpm/ft^2 (6.5 L/min·m^2) of liquid surface area. Minimum discharge time shall be as specified in TABLE 3-2.3.2.2 for Type II fixed foam discharge outlets.

3-5.2.1 If the application rate is higher than the minimum rate specified in 3-5.2, the discharge time can be reduced proportionately, but not less than 70 percent of the minimum discharge times indicated.

3-5.3 Design Criteria for Indoor Storage Tanks Containing Flammable or Combustible Liquids Requiring Alcohol-Resistant Foams. Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to non-alcohol-resistant foams require the use of alcohol-resistant foams. Systems using these foams require special engineering consideration. In all cases, the manufacturers of the foam concentrate and the foam-making equipment shall be consulted as to limitations and for recommendations based on listings or specific fire tests.

3-6* Loading Racks. Within the scope of this standard loading racks are defined as being either truck or rail car types for the purpose of loading or unloading product. Total rack size, flammable or combustible products involved, proximity of other hazards and exposures, drainage facilities, wind conditions, ambient temperatures, and available staff all shall be considered when designing a loading rack foam system. The speed of system operation is always critical in minimizing life and property loss.

3-6.1 Methods of Protection. The following are two acceptable methods of protecting loading racks:

(a) Foam-water sprinkler application utilizing air-aspirating foam-water sprinklers or nozzles or non–air-aspirating standard sprinklers
(b) Foam monitors

3-6.2 Design Criteria for Foam-Water Sprinkler Systems. (For design criteria for sprinkler systems, see NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems.*)

3-6.3 Design Criteria for Foam Monitor Protection Systems.

3-6.3.1* Areas to Be Protected by Monitor Nozzles. Monitor nozzle system design shall be based on the total ground area.

Table 3-6.3.2 Minimum Application Rates and Discharge Times for Loading Racks Protected by Foam Monitor Nozzle Systems

Foam Type	Minimum Application Rate (gpm/ft²)	Minimum Application Rate (L/min·m²)	Minimum Discharge Time (min)	Product Being Loaded
Protein and fluoroprotein	0.16	6.5	15	Hydrocarbons
AFFF, FFFP, and alcohol-resistant AFFF or FFFP	0.10*	4.1	15	Hydrocarbons
Alcohol-resistant foams	Consult manufacturer for listings on specific products		15	Flammable and combustible liquids requiring alcohol-resistant foam

*If a fuel depth of more than 1 in. (25.4 mm) can accumulate within the protected area, the application rate shall be increased to 0.16 gpm/ft² (6.5 L/min·m²).

Table 3-7.1.1 Minimum Application Rates and Discharge Times for Fixed Foam Application on Diked Areas Involving Hydrocarbon Liquids

Type of Foam Discharge Outlets	Minimum Application Rate (gpm/ft²)	Minimum Application Rate (L/min·m²)	Minimum Discharge Time (min) Class I Hydrocarbon	Minimum Discharge Time (min) Class II Hydrocarbon
Low-level foam discharge outlets	0.10	4.1	30	20
Foam monitors	0.16	6.5	30	20

The intent of the design shall be to protect the canopy, pumps, meters, vehicles, and miscellaneous equipment associated with the loading and unloading operation in the event of a spill fire. Although most systems are designed to protect the canopy area only, it is often desirable to protect the total curbed area around the loading rack or the entire length of the truck or rail car.

3-6.3.2 Minimum Application Rates and Discharge Times. Minimum foam application rates and discharge times for loading racks protected by monitor nozzles shall be as specified in Table 3-6.3.2.

3-7* Diked Areas — Outdoor. For the purpose of this standard, diked areas are areas bounded by contours of land or physical barriers that retain a fuel to a depth greater than 1 in. (25.4 mm). Protection of these areas can be achieved by either fixed discharge outlets, fixed or portable monitors, or foam hoselines.

3-7.1 Methods of Application. Where foam protection is considered for a diked area, it can be accomplished by any of the following methods:

(a) Low-level foam discharge outlets

(b) Foam monitors or foam hoselines

(c) Foam-water sprinklers or nozzles

This list of methods shall not be considered as being in the order of preference.

3-7.1.1 Minimum Application Rates and Discharge Times for Fixed Discharge Outlets on Diked Areas Involving Liquid Hydrocarbons. The minimum application rates and discharge times for fixed foam application on diked areas shall be as specified in Table 3-7.1.1.

3-7.1.2 Fixed Foam Discharge Outlets. Fixed foam discharge outlets vary considerably in capacity and range area of coverage. Fixed foam discharge outlets shall be sized and located to apply foam uniformly over the dike area at the application rate specified in Table 3-7.1.1. Large dike areas shall be permitted to be subdivided to keep the total design solution within practical limits.

3-7.1.2.1 Fixed Foam-Water Sprinklers or Nozzles. Where fixed foam-water sprinklers or nozzles are used, the system design shall be in accordance with NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems.*

3-7.1.2.1.1 Limitations. Where foam-water sprinklers or nozzles are used as the primary protection, consideration shall be given to the possibility that some of the foam discharge can be carried by the wind beyond the area of the fuel spill.

Overhead application by foam-water sprinklers or nozzles might need supplementary low-level foam application to provide coverage below large obstructions. Overhead pipework can be susceptible to damage by explosion.

3-7.1.2.2 Fixed Low-Level Foam Discharge Outlets. These outlets shall be permitted to be open pipe fittings or directional flow nozzles designed to discharge a compact, low-velocity foam stream onto the inner wall of the dike or — where necessary — directly onto the dike floor. They shall be located around the dike wall, and — where necessary — inside the dike area, to apply foam uniformly over the dike area.

3-7.1.2.2.1 Limitations. Where fixed discharge outlets installed at a low level are used as the primary protection, they shall be located so that no point in the dike area is more than 30 ft (9 m) from a discharge outlet where the discharge per outlet is 60 gpm (225 L/min) or less.

For outlets having discharge rates higher than 60 gpm (225 L/min) the maximum distance between discharge outlets shall be 60 ft (18 m).

Low-level foam discharge outlets might need supplementary overhead foam spray application to provide coverage or cooling for overhead structures or for tank surfaces.

3-7.1.2.3 Foam Monitors. Where monitors are used to discharge foam onto the dike area, they shall be located outside the dike area.

3-7.1.2.3.1 Limitations. Where foam monitors are used as the primary protection, consideration shall be given to the possibility that some of the foam discharge can be carried by the wind beyond the area of the fuel spill.

Table 3-8.1 Minimum Application Rate and Discharge Times for Nondiked Spill Fire Protection Using Portable Foam Nozzles or Monitors

Foam Type	Minimum Application Rate (gpm/ft²)	Minimum Application Rate (L/min·m²)	Minimum Discharge Time (min)	Anticipated Product Spill
Protein and fluoroprotein	0.16	6.5	15	Hydrocarbon
AFFF, FFFP, and alcohol-resistant AFFF or FFFP	0.10	4.1	15	Hydrocarbon
Alcohol-resistant foams	Consult manufacturer for listings on specific products		15	Flammable and combustible liquids requiring alcohol-resistant foam

Where the monitor discharge is in the form of a compact, high-velocity foam stream, it shall be directed against the dike walls, tank surfaces, or other structures to prevent its plunging directly into the burning liquid surface.

3-7.2 Diked Areas Involving Flammable or Combustible Liquids Requiring Alcohol-Resistant Foams. Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to nonalcohol-resistant foams require the use of alcohol-resistant foams. Systems using these foams require special engineering consideration.

3-7.2.1 Design Criteria for Diked Areas Involving Flammable or Combustible Liquids Requiring Alcohol-Resistant Foams. The design criteria shall be as follows:

(a) Methods of fixed protection shall be the same as those described in 3-7.1.2 for hydrocarbon hazards.

(b) Application rates shall be in accordance with manufacturer recommendations based on listings or approvals for specific products and corresponding foam-making devices.

(c) The minimum discharge time shall be 30 minutes.

3-8 Nondiked Spill Areas. For the purpose of this standard, nondiked spill areas are areas where a flammable or combustible liquid spill might occur, uncontained by curbing, dike walls, or walls of a room or building. In such cases it is assumed that any fire would be classified as a spill fire [i.e., one in which the flammable liquid spill has an average depth not exceeding 1 in. (25.4 mm) and is bounded only by the contour of the surface on which it is lying].

3-8.1 Design Criteria for Protection of Spill Fires Involving Hydrocarbons or Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams. To determine protection for spill fires, it is necessary to estimate the potential spill area. Once this has been determined, Table 3-8.1 shall be used to calculate requirements to be used as design criteria for portable nozzles or monitors.

3-9* Supplementary Protection. In addition to the primary means of protection, some types of hazards require provisions for supplemental means of protection. The supplemental protection requirements are described in this section.

3-9.1 Supplemental Foam Hose Stream Requirements. Approved foam hose stream equipment shall be provided in addition to tank foam installations as supplementary protection for small spill fires. The minimum number of fixed or portable hose streams required shall be as specified in Table 3-9.1 and shall be available to provide protection of the area. The equipment for producing each foam stream shall have a solution application rate of at least 50 gpm (189 L/min), with the minimum number of hose streams shown in Table 3-9.1.

Table 3-9.1 Supplemental Foam Hose Stream Requirements

Diameter of Largest Tank	Minimum Number of Hose Streams Required
Up to 65 ft (19.5 m)	1
65 to 120 ft (19.5 to 36 m)	2
Over 120 ft (36 m)	3

3-9.1.1 Additional foam-producing materials shall be provided to permit operation of the hose stream equipment simultaneously with tank foam installations as specified in Table 3-9.1.1.

Table 3-9.1.1 Hose Stream Operating Times, Supplementing Tank Foam Installations

Diameter of Largest Tank	Minimum Operating Time*
Up to 35 ft (10.5 m)	10 min
35 to 95 ft (10.5 to 28.5 m)	20 min
Over 95 ft (28.5 m)	30 min

*Based on simultaneous operation of the required minimum number of hose streams discharging at a rate of 50 gpm (189 L/min).

Chapter 4 Specifications and Plans

4-1* Preliminary Approval. It is good practice for the owner or his or her designated representative (i.e., architect, contractor, or other authorized person) to review the basic hazard with the authority having jurisdiction to obtain guidance and preliminary approval of the proposed protection concept.

4-2 Approval of Plans. Plans shall be submitted to the authority having jurisdiction for approval before installation.

4-3 Specifications. Specifications for foam systems shall be developed with care and shall include the following:

(a) The specifications shall designate the authority having jurisdiction and shall indicate whether submission of plans is required.

(b) The specifications shall state that the installation shall conform to this standard and shall meet the approval of the authority having jurisdiction.

(c) The specifications shall include the specific tests that might be required to meet the approval of the authority having jurisdiction and shall indicate how testing costs are to be met.

4-4 Plans. Preparation of plans shall be entrusted only to fully experienced and responsible persons. They shall be submitted for approval to the authority having jurisdiction before foam systems are installed or existing systems are modified. These plans shall be drawn to an indicated scale or shall be suitably dimensioned.

4-4.1 The plans shall include or be accompanied by the following information, where applicable:

(a) Physical details of the hazard; including the location, arrangement, and hazardous materials involved

(b) Type and percentage of foam concentrate

(c) Required solution application rate

(d) Water requirements

(e) Calculations specifying required amount of concentrate

(f) Hydraulic calculations (See Chapter 6 of NFPA 13, *Standard for the Installation of Sprinkler Systems*, for hydraulic calculation procedures.)

(g) Identification and capacity of all equipment and devices

(h) Location of piping, detection devices, operating devices, generators, discharge outlets, and auxiliary equipment

(i) Schematic wiring diagram

(j) Explanation of any special features

4-4.2 Complete plans and detailed data describing pumps, drivers, controllers, power supply, fittings, suction and discharge connections, and suction conditions shall be submitted by the engineer or contractor to the authority having jurisdiction for approval before installation.

4-4.2.1 Where field conditions necessitate any significant change from the approved plan, revised "as installed" plans shall be supplied for approval to the authority having jurisdiction.

4-4.3 Charts that specify head, delivery, efficiency, and brake horsepower curves of pumps shall be furnished by the contractor.

Chapter 5 Installation Requirements

5-1* Foam Concentrate Pumps. Pressure shall not exceed the working pressure of the concentrate piping system. Positive displacement pumps and centrifugal pumps capable of overpressuring the system shall be provided with adequate means of pressure relief from the discharge to the supply side of the circuit to prevent excessive pressure and temperature.

5-2 Flushing. Pumps shall have adequate means for flushing with water. They shall be provided with a drain cock or valve.

5-3 Power Supply.

5-3.1 Power supply for the drivers of foam concentrate pumps shall be installed in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, and NFPA 70, *National Electrical Code*.

5-3.2 Power supplies shall be arranged such that disconnecting power from the protected facility during a fire shall not disconnect the power supply to the foam concentrate pump feeder circuit.

5-3.3 A controller governing the start-up of concentrate pumps with electric drivers of 30 horsepower or less shall be listed as limited service controller. A controller governing the start-up of foam concentrate pumps with electric drivers of greater than 30 horsepower shall be listed as fire pump controller. A controller governing the start-up of foam concentrate pumps with diesel engine drivers shall be listed as diesel engine fire pump controller.

5-3.4* A service disconnecting means in the feeder circuits to limited service controllers shall be permitted, where allowed by the authority having jurisdiction, provided the disconnecting means is supervised for the proper position. Supervision for proper position shall be performed by one of the following:

(a) Central station, proprietary, or remote station signaling electrical supervision service

(b) Local electrical supervision through use of a signaling service that will cause the sounding of an audible signal at a constantly attended point

(c) Locking the disconnect in the correct position with monthly recorded inspections

5-4 Piping.

5-4.1 General Requirements.

5-4.1.1 All piping inside of dikes or within 50 ft (15 m) of tanks not diked shall be buried under at least 1 ft (0.3 m) of earth or, if aboveground, shall be properly supported and protected against mechanical injury.

5-4.1.2 Piping that is subject to freezing shall be installed for proper drainage with a pitch of $^1/_2$ in. for every 10 ft (4 mm per m) or shall be protected from freezing temperatures.

5-4.1.3 For systems that apply foam to a tank's liquid surface from the top side, all piping within the dike or within 50 ft (15 m) of tanks not diked shall be designed to absorb the upward force and shock caused by a tank roof rupture. One of the following designs shall be used:

(a) *Piping less than 4 in. (101.6 mm) in diameter.*

1. Where piping is buried, a swing joint or other suitable means shall be provided at each tank riser to absorb the upward force. The swing joint shall consist of approved standard weight steel, ductile, or malleable iron fittings.
2. Where piping is supported aboveground, it shall not be secured for a distance of 50 ft (15 m) from the tank shell to provide flexibility in an upward direction so that a swing joint is not needed. If there are threaded connections within this distance, they shall be back welded for strength.

(b) **The vertical piping of 4 in. (101.6 mm) in diameter and greater on the protected tank shall be provided with one brace at each shell course.* This design can be used in lieu of swing joints or other approved aboveground flexibility, as specified in 5-4.1.3(a)1 and 5-4.1.3(a)2.

5-4.1.4 One flange or union joint shall be provided in each riser at a convenient location, preferably directly below the foam maker, to permit hydrostatic testing of the piping system up to this joint. With all welded construction, this might be the only joint that can be opened.

5-4.1.5 In systems with semifixed equipment on fixed-roof tanks, the foam or solution laterals to each foam maker shall terminate in connections that are located at a safe distance from the tanks. These connections shall not be located within the dike. Connections shall be located at a distance of at least one tank diameter from the tank but in no case less than 50 ft (15 m). The inlets to the piping shall be fitted with corrosion-resistant metal connections, compatible with the equipment supplying foam solution to the system, and provided with plugs or caps.

5-5 Valves in Systems.

5-5.1 The laterals to each foam discharge outlet on fixed-roof tanks shall be separately valved outside the dike in fixed installations. Shutoff valves to divert the foam or solutions to the proper tank shall be located either in the central foam station or at points where laterals to the protected tanks branch from the main feed line. These valves shall not be located within the dike. Valves shall be located at a distance of at least one tank diameter from the tank but in no case less than 50 ft (15 m).

Exception: Shutoff valves can be permitted to be located at shorter distances where remotely operated, subject to the approval of the authority having jurisdiction.

5-5.2 Where two or more foam proportioners are installed in parallel and discharge into the same outlet header, valves shall be provided between the outlet of each device and the header. The water line to each proportioner inlet shall be separately valved.

5-5.3 For subsurface applications, each foam delivery line shall be provided with a valve and a check valve unless the latter is an integral part of the high back-pressure foam maker or pressure generator to be connected at the time of use. Where product lines are used for foam, product valving shall be arranged to ensure foam enters only the tank to be protected.

5-5.4 Drain valves that are readily accessible shall be provided for low points in underground and aboveground piping.

5-6 Hangers, Supports, and Protection for Pipework.

5-6.1 Where protecting hazards where there is a possibility of explosion, pipework shall be routed to afford the best protection against damage. The supply piping to foam outlets that protect a given hazard in a fire area shall not pass over another hazard in the same fire area.

5-6.2 All hangers shall be of approved types. Tapping or drilling of load-bearing structural members shall not be permitted where unacceptable weakening of the structure would occur. Attachments can be made to existing steel or concrete structures and equipment supports. Where systems are of such a design that the standard method of supporting pipe for protection purposes cannot be used, the piping shall be supported in such a manner as to produce the strength equivalent to that afforded by the standard means of support.

5-7 Hose Requirements. Unlined fabric hose shall not be used with foam equipment.

Chapter 6 Marine Applications

6-1* General. This chapter covers design information for the use of low-expansion foam systems that are necessary for marine applications where required by the authority having jurisdiction. The provisions of Chapters 2, 3, 4, and 5 of this standard are not applicable unless specifically referenced.

6-1.1* All components shall be suitable for their intended application and shall be approved for use in a marine environment.

6-1.1.1 Each manufacturer shall maintain a system design manual describing basic acceptable system design arrangements and denoting each of the manufacturer's products within the system.

6-1.2 Foam concentrates shall be approved.

6-1.2.1 The concentrate used in a foam system for protecting a flammable or combustible liquid shall be approved for hydrocarbons in accordance with a test method equivalent to the 100 ft^2 (9.29 m^2) hydrocarbon method given in Appendix F.

Four consecutive fire tests shall be completed; two using sea water, and two using fresh water.

6-1.2.2* Concentrates intended for use on polar solvent systems shall be approved for hydrocarbons in accordance with 6-1.2.1 and approved for use on polar solvents in accordance with a method equivalent to UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates.*

6-1.3 The foam supply shall be in accordance with 2-3.2.2.

6-1.4 The water supply shall be in accordance with 2-2.1.1, 2-2.1.2, and 2-2.1.3.

6-1.5 The foam system shall be capable of being actuated, including introduction of foam solution into the foam main within 3 minutes of notification of a fire.

6-2 Fixed Low-Expansion Foam Systems for Machinery Spaces.

6-2.1* Where installed, systems protecting machinery spaces shall be capable of discharging a sufficient quantity of expanded foam to provide a foam depth of at least 6 in. (150 mm) over the largest area over which oil is likely to spread. The minimum foam solution application rate shall be 0.16 gpm/ft^2 (6.5 L/min·m^2) for a minimum of 5 minutes. The system shall be capable of generating foam suitable for extinguishing hydrocarbon fires. Means shall be provided for effective distribution of the foam through a permanent system of piping and control valves to suitable discharge outlets and for foam to be effectively directed by fixed foam outlets. The foam expansion ratio shall not exceed 12:1.

6-2.1.1 Where a deck foam system is also installed, the foam supply and proportioning system need not be separate. The quantity of foam concentrate shall be that required to meet the single largest system demand.

6-2.2 System controls shall be readily accessible, simple to operate, and grouped together in a location accessible during fire conditions in the protected area. Instructions in clear and permanent lettering shall be affixed to the equipment or in a position adjacent thereto. Remotely controlled devices shall have local mechanical override.

6-3 Fixed Low-Expansion Foam Systems on Deck for Petroleum and Chemical Tankers.

6-3.1* Purpose. The purpose of this section is to provide guidance for the design and arrangement of deck foam systems that are expected to provide the following performance:

(a) Extinguish deck spill fires and maintain a foam blanket while hot metal cools.

(b) Control or suppress cargo manifold fires except those involving three-dimensional pressurized liquid fires.

(c) Suppress or control tank fires involving a portion of the cargo area assuming that the top of the tank(s) within the design area is open to weather and that the trajectory of the foam is not obstructed.

(d) Provide protection for the crew while arrangements are being made to abandon ship.

(e) During lightering operations, the deck foam system flowing water should protect the exposed vessel from fire on an adjacent ship while preparations are made to get the exposed vessel under way.

(f) The deck foam system is not intended to provide extinguishment, suppression, or control of incidents resulting from major explosions or collisions that cause the fire to exceed the area of the single largest tank.

(g) The deck foam system shall be designed and arranged to withstand the effects of weather, vibration, corrosion, strain, and impact expected during the ship's operation.

(h) Suppress vapors from an unignited spill on deck.

6-3.2 Control Station.

6-3.2.1 The main control station for the system shall be located aft of the cargo area and readily accessible and operable in the event of fire in the main area protected.

6-3.2.2* Operating instructions and diagrams of piping systems and valves shall be provided in clear and permanent lettering and shall be affixed to the equipment or in a position near thereto. The diagrams shall show which valves are to be opened in the event the system must be activated. The diagrams shall explain thoroughly and clearly all the steps necessary to put the system into operation. Each valve shall be labeled describing its function.

6-3.2.3 The control station shall be provided with emergency lighting.

6-3.3* Fire Main Capacity. Operation of a deck foam system at its required foam solution flow rate shall still permit the simultaneous use of the required number of streams of water and other services provided by the fire main system.

6-3.4* Rate of Application. The rate of application of foam solution for fires on deck shall not be less than the greatest of the following.

(a) *For Hydrocarbon Fuels:*

1. Deck spill calculation — 0.16 gpm/ft^2 (6.50 L/min·m^2) over 10 percent of the cargo block deck area, where the cargo block deck area is the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces.
2. Largest tank calculation — 0.24 gpm/ft^2 (9.78 L/min·m^2) of the horizontal sectional area of the single largest tank.
3. Largest monitor calculation — 0.074 gpm/ft^2 (3.0 L/min·m^2) of the area protected by the largest monitor, such area being entirely forward of the monitor, but not less than 330 gpm (1250 L/min).

(b) *For Polar Solvents:* Since required foam application rates may vary, polar solvents are placed in representative groups based upon fire performance tests. Fire tests are used to determine the minimum foam design application rate for the group and are conducted using one or more solvents representing the most difficult extinguishment case or the actual polar solvent. These minimum foam design application rates and polar solvent groupings shall be specified in the foam manufacturer's system design manual and shall be approved.

1. Deck spill calculation — The highest required foam application rate for any polar solvent that can be transported by the ship, applied over 10 percent of the cargo block deck area, where the cargo block deck area is the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces.
2. Most demanding tank calculation — 150 percent of the highest required foam application rate, for any polar solvent that can be transported by the ship, applied over the horizontal sectional area of the single largest tank.

Exception to 2: Where dedicated cargo tanks are specifically designed for a particular polar solvent and such solvent cannot be carried in other tanks, the foam system design can take into consideration this limitation.

3. Largest monitor calculation — 45 percent of the highest required foam application rate for any polar solvent that can be transported by the ship, applied over the area protected by the foam monitor, such area being entirely forward of the monitor, but not less than 330 gpm (1250 L/min).

6-3.5 Discharge Duration.

6-3.5.1* Foam concentrate shall be provided to supply the system for 30 minutes.

Exception: For ships that are both transporting only hydrocarbons and using gas inerting of cargo vapor spaces, the discharge duration shall be permitted to be 20 minutes.

6-3.5.2 Allowance shall be made to fill all foam solution and concentrate piping and still provide the required duration.

6-3.5.3* Minimum discharge duration shall be based on the actual capacity of the installed equipment.

6-4* Foam Outlet Devices. One hundred percent of the required foam application shall be by using one or two monitors located immediately aft of the protected area.

Exception: On tankers less than 4000 tons dead weight, hand hoselines only can be installed provided that the capacity of each hand hoseline is at least 25 percent of the total foam solution flow rate.

6-5 Monitors.

6-5.1 The capacity of any monitor shall be at least 0.074 gpm/ft^2 (3.02 L/m·m^2) of the deck area protected by that monitor, with such area being entirely forward of the monitor. The capacity of each monitor shall be not less than 50 percent of the required foam application rate and not less than 330 gpm (1250 L/min).

6-5.2 The distance from the monitor to the farthest extremity of the protected area forward of the monitor shall be not more than 75 percent of the monitor throw in still air conditions.

6-5.3 Foam monitors and hand hoseline connections shall be situated both port and starboard at the front of the accommodation space facing the cargo tank's deck. These monitors shall be located at least 8.2 ft (2.5 m) above the main deck and shall be directly accessible to the deck above the freeboard deck.

Exception: Monitors are not required on tankers less than 4000 metric tons dead weight.

6-5.4 The foam system shall be capable of delivering foam to the entire cargo block deck area.

6-5.4.1 Ships fitted with bow or stern loading and unloading arrangements shall be provided with one or more additional monitors located to protect the bow or stern arrangements. The area of the cargo line fore or aft of the cargo block area shall be provided with monitor protection.

6-5.5 Foam monitors shall be mounted on substantial platforms. Platforms shall permit 360 degree access around the monitors. Platforms shall be raised to allow the monitors an unobstructed throw insofar as practical. The monitor isolation valve shall be accessible from the monitor platform. Platforms higher than 6.5 ft (2 m) shall be provided with hand rails or chain rails. Access to the monitor platform shall be via walkway or permanent ladder. Provisions shall be made for securing monitors while at sea.

6-5.6 Monitors over 1000 gpm (3785 L/min) shall be provided with two operator handholds or one handwheel for each swivel. Monitors shall be designed to prevent unwanted movement due to reaction forces. Monitors shall be capable of being locked into position while operating at full flow.

6-6 Hand Hoselines.

6-6.1 Hand hoselines shall be provided to ensure flexibility of action during fire-fighting operations and to cover areas obstructed from monitors. The capacity of any hand hoseline shall be not less than 106 gpm (401 L/min) and the hand hoseline throw in still air conditions shall be not less than 50 ft (15 m). The number and location of foam solution outlets shall be such that foam from at least two hand hoselines can be simultaneously directed onto any part of the cargo block deck area.

6-6.2 Hand hoselines and hydrants shall be mounted on monitor platforms or at deck level.

6-7 Hydraulic Calculations. Hydraulic calculations shall be performed in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection.* Foam solution shall be considered to have the same hydraulic characteristics as water.

6-7.1 Foam concentrate hydraulic calculations shall be in accordance with the foam concentrate manufacturer's system design manual.

6-7.2 Orifices shall be permitted to balance flows to monitors and fixed foam outlets.

6-8 Isolation Valves.

6-8.1 Isolation valves shall be provided in the water, foam concentrate, and foam solution mains (immediately forward of any monitor position) to isolate damaged sections. In addition, each monitor and hose station shall have an isolation valve. Isolation valves shall be operable from readily accessible locations. Monitor isolation valves shall be in accordance with 6-5.5. All isolation valves shall be installed with the bonnet above the horizontal.

6-8.2 Isolation valves shall be provided with a ready means for visual indication of valve position.

6-9 Hangers, Supports, and Protection of Pipework.

6-9.1 Pipework shall be routed to afford protection against damage.

6-9.2* All hangers and piping supports shall be designed for marine applications.

6-9.3* Deck foam solution piping shall be independent of fire main piping. Where the fire main and foam main are connected to a common monitor, check valves shall be installed.

6-9.4* The system shall be arranged to prevent the possibility of freezing. Portions of the system exposed to weather shall be self-draining. Wet or pressurized portions of the system shall be protected against freezing.

6-10 Testing and Inspection.

6-10.1* Foam systems shall be inspected and tested in accordance with Chapter 6 and Chapter 7. Annual testing shall include tests conducted in accordance with 7-3.3.

6-10.2 The system supplier or owner shall make available to the ship's crew a system use, inspection, and testing videotape.

6-11 Foam System Concentrate Storage.

6-11.1 Foam concentrate storage shall be in accordance with 2-3.2.4.

6-11.1.1* The primary deck foam concentrate storage tank shall be located on or above the freeboard deck level in the space containing the system control station described in 6-3.2. All foam concentrate shall be stored in an accessible location unlikely to be cut off in the event of fire or explosion and not having direct opening or exposure to the cargo area.

6-11.2 Foam concentrate tanks shall be in accordance with 2-3.2.3.

6-11.2.1* Tanks shall have expansion domes. Tanks shall be fitted with baffles to prevent sloshing. Each concentrate storage tank shall be provided with a brass, stainless steel, or other corrosion-resistant pressure vacuum (PV) vent. Each tank shall have a substantial support structure suitable for mounting the tank to the ship's structure. Each tank shall have a sump or other means to prevent clogging of the foam concentrate suction pipe in the event of sedimentation or other foreign materials in the tank. The foam concentrate suction pipe shall take suction above the bottom of the sump.

6-11.3 Tanks shall be of a design and materials proven to be suitable for use with constant sloshing of the liquid against the tank structure.

6-11.4 Each tank shall have a manway or openings for internal inspection and access.

6-11.5 Tank suction and return connections shall terminate near the bottom of the tank so as to reduce the chance of premature foaming due to agitation during system operation.

6-11.6 Atmospheric tanks shall be provided with means for continuous refilling of the tank.

6-11.7 Foam concentrate storage shall be within the foam concentrate manufacturer's recommended temperature limitations. Storage spaces shall be provided with heat to prevent freezing of the foam concentrate and piping. Storage shall be in accordance with 2-3.2.4 and 2-3.2.4.1.

6-11.8 Foam concentrate compatibility shall be in accordance with 2-4.1 and 2-4.2. The foam concentrate storage tank shall be provided with a label specifying foam manufacturer, foam type, and quantity.

6-11.9 Only one type of foam concentrate shall be carried on board.

Table 6-13.1 Piping Materials

Service	Pipe	Valves	Fittings	Takedown joints
Seawater or foam solution (up to 225 psi and 350°F)	Carbon steel, seamless or electric resistance weld, standard wall, galvanized[1,2]. ASTM A 53, Type E or S, Gr. A or A 106, Gr. A Schedule 40 minimum	*Body:* Carbon steel, ASTM A 216 Gr. WCB or Ductile iron, ASTM A 395 *Trim:* Bronze or 316 SS *Ends:* Flanged ANSI B16.5 Class 150	*3 in. and larger:* Wrought steel, standard wall, galvanized per ANSI B16.9, 150 lb minimum *2 in. and smaller:* Socket weld steel, 2000#, galvanized per ANSI B16.11 ASTM A 234 Gr. WPB	*3 in. and larger:* Slip-on or buttweld flange *2 in. and smaller:* Socket weld flange ANSI B16.5 Class 150, ASTM A 105
Foam concentrate (in the hazard area)	Carbon steel, seamless or electric resistance weld, standard wall. ASTM A 53, Type E or S, Gr. or A 106, Gr. A OR Stainless steel, seamless, standard wall pipe ASTM A 312 Gr. TP304L or TP316L	*Body:* Carbon steel, ASTM A 216 Gr. WCB or A 105 *Trim:* 304L or 316L SS *Ends:* Flanged ANSI B16.5 Class 150 or screwed OR *Body:* Forged stainless steel, ASTM A 182 Gr. F304L or F316L *Trim: 304L or 316L SS* *Ends:* Flanged ANSI B16.5 Class 150 or screwed	Socket weld or threaded carbon steel, 2000# per ANSI B16.11 ASTM A 234 Gr. WPB OR Socket weld or threaded stainless steel, 2000# per ANSI B16.11 ASTM A 182 Gr. F304L or F316L	Screwed or socket weld flange per ANSI B16.5 Class 150 ASTM A 105 or ASTM A 182 Gr. 304L or Gr. 316L OR Screwed or socket weld union, 2000# per ANSI B16.11 ASTM A 105 or ASTM A 182 Gr. 304L or Gr. 316L

Note: Standards shown are minimum acceptable. Equivalent foreign standards may be used if approved.
[1]System may be assembled using black steel pipe and fittings, hot dip galvanized after fabrication.
[2]Where pipe and fittings are galvanized, all disturbed areas are to be repaired using suitable cold galvanizing product.
For SI units: 1 psi = 6.895 kPa; 5/9 (degrees F – 32) = degrees C.

6-12 Supply Arrangements.

6-12.1* Foam proportioning shall be by the balanced pressure proportioning method employing a dedicated foam concentrate pump.

Exception: Other types of systems acceptable to the authority having jurisdiction shall be permitted.

6-12.2* Foam concentrate pumps shall be in accordance with Section 2-6.

6-12.3* Foam and water pump motors and controllers shall comply with IEEE Standard 45, *Recommended Practice for Electric Installations,* or equivalent.

6-12.4 Foam and water pumps shall be capable of operation during loss of the main power system.

6-12.5 Electric power for foam pumps, water pumps, and other electrical components of the foam system shall be in accordance with the provisions of SOLAS Regulations II-2, Section 4.3 and 4.3.5 applicable to fire pumps.

6-12.6 Where diesel pumps are provided, they shall be connected to a listed diesel pump controller.

6-12.7 The deck foam system piping shall not be routed through, immediately adjacent to, or immediately above the cargo pump room.

6-13 Piping Materials.

6-13.1 Piping shall be in accordance with Table 6-13.1. Other materials may be used provided they have physical properties and corrosion resistance equivalent to the piping identified in Table 6-13.1 and are approved by the authority having jurisdiction.

6-13.2 Pipe in areas subject to fire exposure, including radiant and conducted heat, shall be of steel or other alloy suitable for the pressure, possible fire temperature exposure, and environmental conditions expected.

6-13.3 Foam concentrate piping shall be constructed of material compatible with, and not affected by, the concentrate. Foam concentrate piping shall not be galvanized.

6-13.4* Pipe thread joint sealants used for foam concentrate lines shall be in accordance with the foam concentrate manufacturer's recommendations.

Chapter 7 Testing and Acceptance

7-1 Inspection and Visual Examination. Foam systems shall be examined visually to determine that they have been properly installed. They shall be inspected for such items as conformity with installation plans; continuity of piping; removal of temporary blinds; accessibility of valves, controls, and gauges; and proper installation of vapor seals, where applicable. Devices shall be checked for proper identification and operating instructions.

7-2 Flushing after Installation. In order to remove foreign materials that might have entered both underground and aboveground water supply mains during installation, they shall be flushed thoroughly at the maximum practicable rate of flow before connection is made to system piping. The minimum rate of flow for flushing shall not be less than the water demand rate of the system, as determined by the system design. The flow shall be continued for a sufficient time to ensure thorough cleaning. Disposal of flushing water must be suitably arranged. All foam system piping shall be flushed after installation, using the system's normal water supply with foam-forming materials shut off, unless the hazard cannot be subjected to water flow. Where flushing cannot be accomplished, pipe interiors shall be carefully visually examined for cleanliness during installation.

7-3* Acceptance Tests. The completed system shall be tested by qualified personnel to meet the approval of the authority having jurisdiction. These tests shall be adequate to determine tions as intended.

7-3.1 Pressure Tests. All piping, except piping handling expanded foam for other than subsurface application, shall be subjected to a 2-hour hydrostatic pressure gauge test at 200 psi (1379 kPa) or 50 psi (345 kPa) in excess of the maximum pressure anticipated, whichever is greater, in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.* All normally dry horizontal piping shall be inspected for drainage pitch.

7-3.2 Operating Tests. Before approval, all operating devices and equipment shall be tested for proper function.

7-3.3* Discharge Tests. Where conditions permit, flow tests shall be conducted to ensure that the hazard is fully protected in conformance with the design specification. The following data shall be required:

(a) Static water pressure

(b) Residual water pressure at the control valve and at a remote reference point in the system

(c) Actual discharge rate

(d) Consumption rate of foam-producing material

(e) Concentration of the foam solution

(f) Foam quality (expansion and $^1/_4$ drain time) or foam discharge shall be conducted or the foam discharge shall be visually inspected to ensure that it is satisfactory for the purpose intended.

7-3.3.1 Foam concentration shall have one of the following proportions:

(a) Not less than the rated concentration

(b)* No more than 30 percent above the rated concentrate, or 1 percentage point above the rated concentration (whichever is less)

For information on tests for physical properties of foam, see Appendix C.

7-4 System Restoration. After completion of acceptance tests, the system shall be flushed and restored to operational condition.

Chapter 8 Maintenance

8-1 Periodic Inspection. At least annually, all foam systems shall be thoroughly inspected and checked for proper operation. The inspection shall include performance evaluation of the foam concentrate or premix solution quality or both. Test results that deviate more than 10 percent from those recorded in acceptance testing shall be discussed immediately with the manufacturer. Regular service contracts are recommended. The goal of this inspection and testing shall be to ensure that the system is in full operating condition and that it remains in that condition until the next inspection. The inspection report, with recommendations, shall be filed with the owner. Between the regular service contract inspections or tests, the system shall be inspected by competent personnel following an approved schedule.

8-1.1* Foam-Producing Equipment. Proportioning devices, their accessory equipment, and foam makers shall be inspected.

8-1.1.1 Fixed discharge outlets equipped with frangible seals shall be provided with suitable inspection means to permit proper maintenance and for inspection and replacement of vapor seals.

8-1.2 Piping. Aboveground piping shall be examined to determine its condition and to verify that proper drainage pitch is maintained. Pressure tests of normally dry piping shall be made when visual inspection indicates questionable strength due to corrosion or mechanical damage. Underground piping shall be spot-checked for deterioration at least every 5 years.

8-1.3 Strainers. Strainers shall be inspected periodically and shall be cleaned after each use and flow test.

8-1.4 Detection and Actuation Equipment. Control valves, including all automatic and manual-actuating devices, shall be tested at regular intervals.

8-2 Foam Concentrate Inspection. At least annually, an inspection shall be made of foam concentrates and their tanks or storage containers for evidence of excessive sludging or deterioration. Samples of concentrates shall be sent to the manufacturer or qualified laboratory for quality condition testing. Quantity of concentrate in storage shall meet design requirements, and tanks or containers shall normally be kept full, with adequate space allowed for expansion.

8-3 Operating Instructions and Training. Operating and maintenance instructions and layouts shall be posted at control equipment with a second copy on file. All persons who are expected to inspect, test, maintain, or operate foam-generating apparatus shall be thoroughly trained and training shall be kept current over time.

Chapter 9 Referenced Publications

9-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix G.

9-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1996 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 1996 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems,* 1995 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps,* 1996 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 1996 edition.

NFPA 70, *National Electrical Code®,* 1996 edition.

NFPA 72, *National Fire Alarm Code®,* 1996 edition.

9-1.2 ANSI Publications. American National Standards Institute, Inc., 11 West 42nd St., 13th Floor, New York, NY 10036.

ANSI B1.20.1, *Pipe Threads,* 1992.

ANSI B16.1, *Cast Iron Pipe Flanges and Flanged Fittings,* 1989.

ANSI B16.3, *Malleable Iron Threaded Fittings,* 1992.

ANSI B16.4, *Gray Iron Threaded Fittings,* 1992.

ANSI B16.5, *Pipe Flanges and Flanged Fittings,* 1996.

ANSI B16.9, *Factory-Made Wrought Steel Buttwelding Fittings,* 1993.

ANSI B16.11, *Forged Fittings, Socket-Welding and Threaded,* 1996.

ANSI B16.25, *Buttwelding Ends,* 1992.

9-1.3 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 53, *Standard Specification for Pipe Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless,* 1996.

ASTM A 105, *Standard Specification for Carbon Steel Forgings for Piping Applications,* 1996.

ASTM A 135, *Standard Specification for Electric Resistance-Welded Pipe,* 1989.

ASTM A 182, *Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service,* 1996.

ASTM A 216, *Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service,* 1993.

ASTM A 234, *Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures,* 1990.

ASTM A 312, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes,* 1995.

ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures,* 1998.

ASTM A 795, *Standard Specification for Black and Hot-Dipped, Zinc-Coated, (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use.*

9-1.4 AWS Publication. American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

AWS D10.9, *Standard for the Qualification of Welding Procedures and Welders for Piping and Tubing,* 1980.

9-1.5 API Publication. American Petroleum Institute, 120 L Street Northwest, Washington, DC 20005.

API 650, *Welded Steel Tanks for Oil Storage,* 1993.

9-1.6 IEEE Publication. Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

IEEE 45, *Recommended Practice for Electric Installations,* 1983.

9-1.7 IMO Publication. International Maritime Organization. Safety of Life at Sea. SOLAS Regulations II-2/4.3 and 4.3.5.

9-1.8 UL Publication. Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates,* 1989.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-4 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-4 Authority Having Jurisdiction. The phrase "authority having jurisdiction" 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 authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 Eductor (Inductor).

Air Foam Hose Nozzle with Built-in Eductor. Figure A-1-4(a) shows the type of proportioner in which the jet in the foam maker is utilized to draft the concentrate.

Limitations. The bottom of the concentrate container should not be more than 6 ft (1.8 m) below the level of the foam maker.

The length and size of hose or pipe between the concentrate container and the foam maker should conform to the recommendations of the manufacturer.

Hydrocarbon Surfactant-Type Foam Concentrates. These are synthetic foaming agents generally based on a hydrocarbon surface active agent. They produce foams of widely different character (expansion and drainage times), depending on the type of foam-producing devices employed. In general, such foams do not provide the stability and burn-back resistance of protein-type foams or the rapid control and extinguishment of AFFF, but they can be useful for petroleum-product spill fire fighting in accordance with their listings and approvals.

There are hydrocarbon-base foaming agents that have been listed as foaming agents, wetting agents, or combination foaming/wetting agents. The appropriate listings should be consulted to determine proper application rates and methods.

A-1-4 Foam Generating Methods. Foam nozzle and monitor streams may also be employed for the primary protection of process units and buildings, subject to the approval of the authority having jurisdiction. The discharge characteristics of the equipment selected to produce foam nozzle and monitor streams for outdoor storage tank protection should be verified by actual tests to make certain that the streams will be effective on the hazards involved. *[See Figures A-1-4(b) through A-1-4(f).]*

A-1-4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Figure A-1-4(c) Adjustable straight stream-to-fan pattern foam-water monitor.

Figure A-1-4(a) Air foam hose nozzle with built-in eductor.

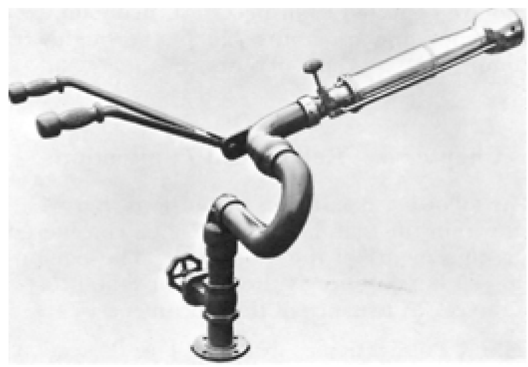


Figure A-1-4(d) Adjustable straight stream-to-spray foam-water monitor.

Figure A-1-4(b) Handline foam nozzle.

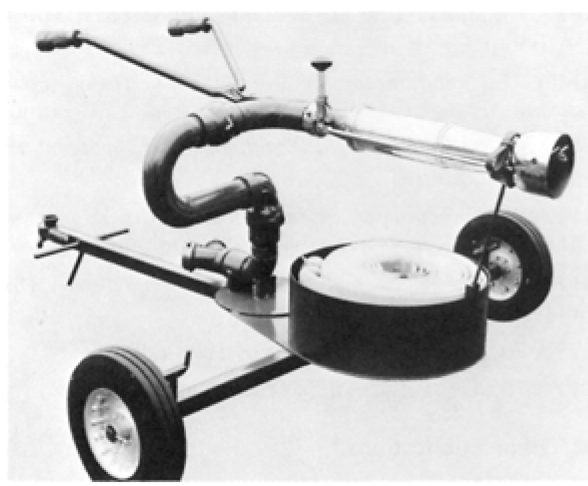


Figure A-1-4(e) Wheeled portable foam-water monitor.

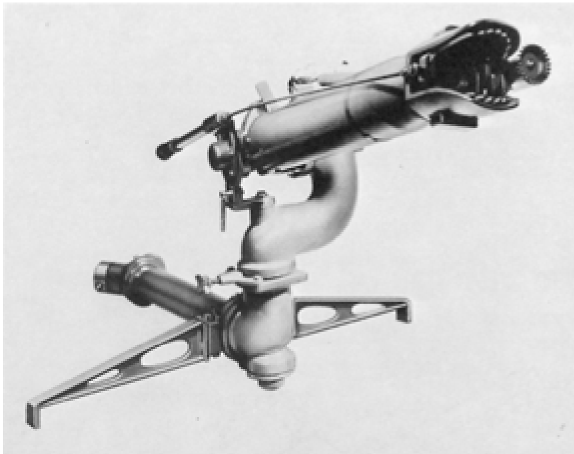


Figure A-1-4(f) Portable foam-water monitor.

A-1-4 Proportioning Methods for Air Foam Systems.

(c) In-Line Eductor. This eductor is for installation in a hoseline, usually at some distance from the foam maker or playpipe, as a means of drafting air foam concentrate from a container. *[See Figures A-1-4(g) and (h).]*

It has the following limitations:

(a) The in-line eductor must be designed for the flow rate of the particular foam maker or playpipe with which it is to be used. The device is very sensitive to downstream pressures and accordingly is designed for use with specified lengths of hose or pipe located between it and the foam maker.

(b) The pressure drop across the eductor is approximately one-third of the inlet pressure.

(c) The elevation of the bottom of the concentrate container should not be more than 6 ft (1.8 m) below the eductor.

(d) Metered Proportioning. By means of an auxiliary pump, foam compound is injected into the water stream passing through an inductor. The resulting foam solution is then delivered to a foam maker or playpipe. The proportioner can be inserted into the line at any point between the water source and foam maker or playpipe. *[See Figures A-1-4(i) and (j).]*

Figure A-1-4(g) In-line eductor.

To operate, the main water valve is opened and a reading of the pressure indicated on the duplex gauge is taken. When both gauge hands are set at the same point, the proper amount of foam concentrate is being injected into the water stream. This is done automatically by the use of a differential pressure diaphragm valve.

Metered proportioning has the following limitations:

(a) The capacity of the proportioner can be varied from approximately 50 percent to 200 percent of its rated capacity.

(b) The pressure drop across the proportioner ranges from 5 psi to 30 psi (34 kPa to 207 kPa), depending on the volume of water flowing through the proportioner within the capacity limits of item (a) above.

(c) A separate pump is needed to deliver concentrate to the proportioner.

(e) Pressure Proportioning Tank. This method employs water pressure as the source of power. With this device, the water supply pressurizes the foam concentrate storage tank. At the same time, water flowing through an adjacent venturi or orifice creates a pressure differential. The low-pressure area of the venturi is connected to the foam concentrate tank, so that the difference between the water supply pressure and this low-pressure area forces the foam concentrate through a metering orifice and into the venturi. Also, the differential across the venturi varies in proportion to the flow, so one venturi will proportion properly over a wide flow range. The pressure drop through this unit is relatively low. *[See Figure A-1-4(k).]*

A special test procedure is available to permit the use of a minimum amount of concentrate when testing the pressure proportioner system.

The pressure proportioning tank has the following limitations:

(a) Foam concentrates with specific gravities similar to water can create a problem when mixed.

(b) The capacity of these proportioners can be varied from approximately 50 percent to 200 percent of their rated capacity.

(c) The pressure drop across the proportioner ranges from 5 psi to 30 psi (34 kPa to 207 kPa), depending on the volume of water flowing within the capacity limits of item (b) above.

(d) When the concentrate is exhausted, the system must be turned off, and the tank drained of water and refilled with foam concentrate.

(e) Since water enters the tank as the foam concentrate is discharged, the concentrate supply cannot be replenished during operation, as with other methods.

(f) This system proportions at a significantly reduced percentage at low flow rates and should not be used below minimum design flow rate.

Diaphragm (Bladder) Pressure Proportioning Tank. This method also uses water pressure as a source of power. This device incorporates all the advantages of the pressure proportioning tank with the added advantage of a collapsible diaphragm that physically separates the foam concentrate from the water supply.

Diaphragm pressure proportioning tanks operate through a similar range of water flows and according to the same principles as pressure proportioning tanks. The added design feature is a reinforced elastomeric diaphragm (bladder) that can be used with all concentrates listed for use with that particular diaphragm (bladder) material. *[See Figure A-1-4(l).]*

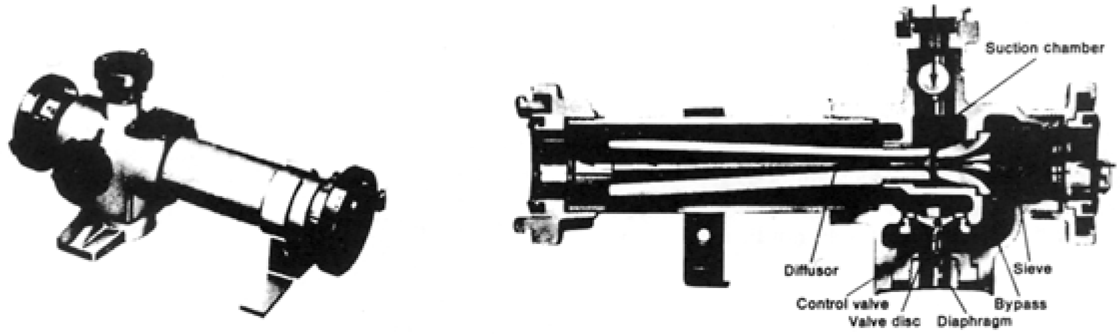


Figure A-1-4(h) In-line eductor.

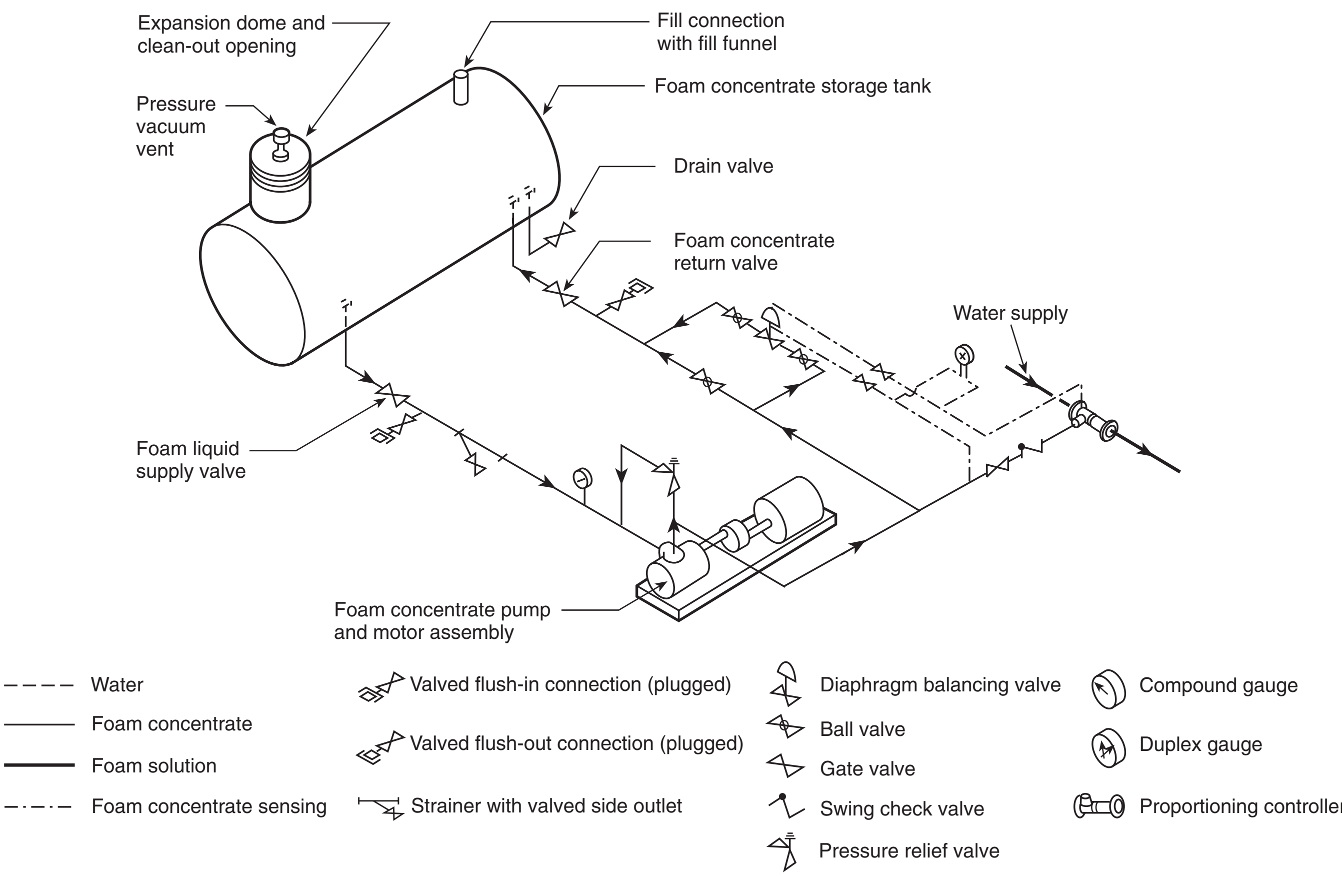


Figure A-1-4(i) Balanced pressure proportioning with single injection point (metered proportioning).

The proportioner is a modified venturi device with a foam concentrate feed line from the diaphragm tank connected to the low-pressure area of the venturi. Water under pressure passes through the controller, and part of this flow is diverted into the water feed line to the diaphragm tank. This water pressurizes the tank, forcing the diaphragm filled with foam concentrate to slowly collapse. This forces the foam concentrate out through the foam concentrate feed line and into the low-pressure area of the proportioner controller. The concentrate is metered by use of an orifice or metering valve and mixes in the proper proportion with the main water supply, sending the correct foam solution downstream to the foam makers.

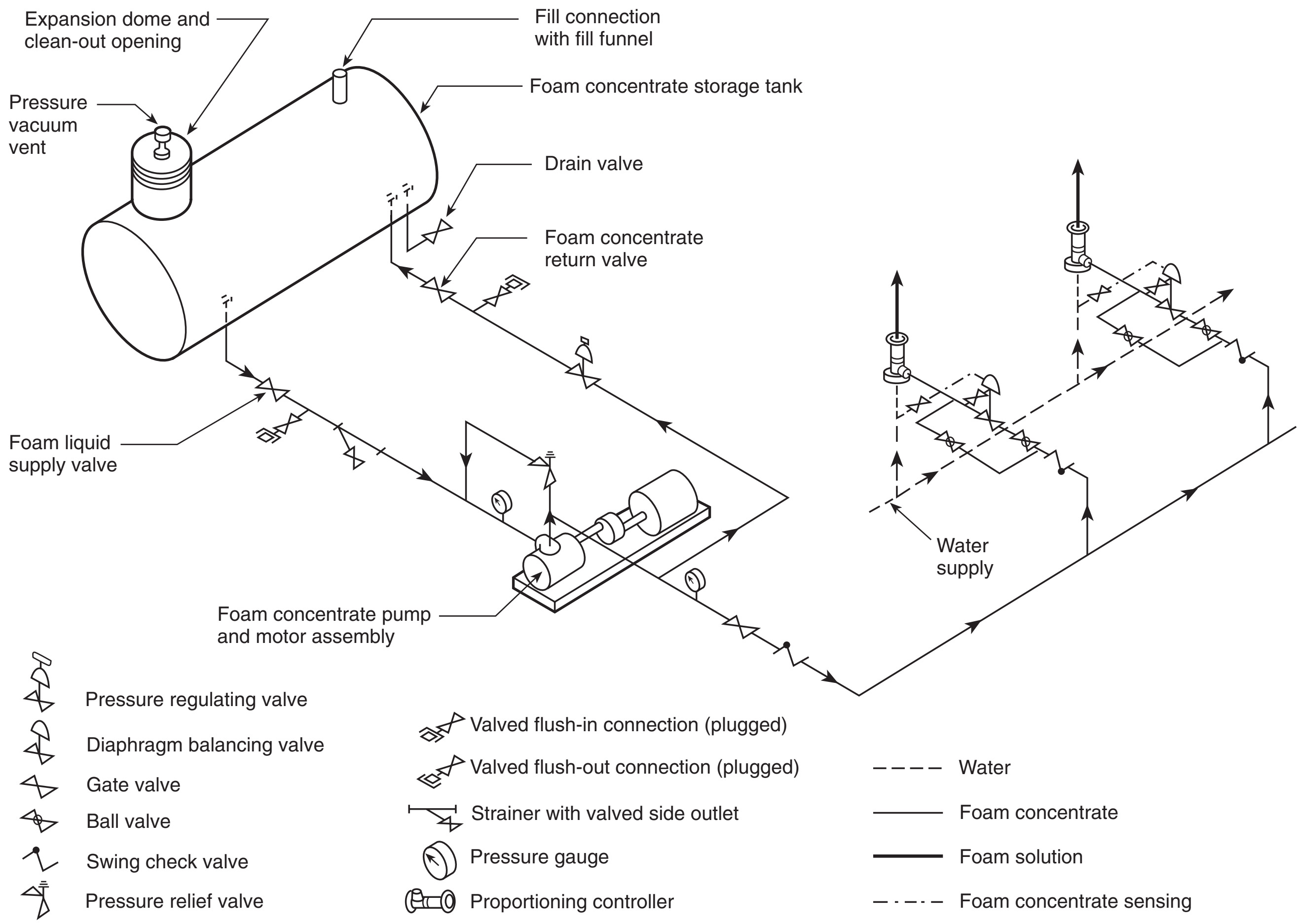


Figure A-1-4(j) Balanced pressure proportioning with multiple injection points (metered proportioning).

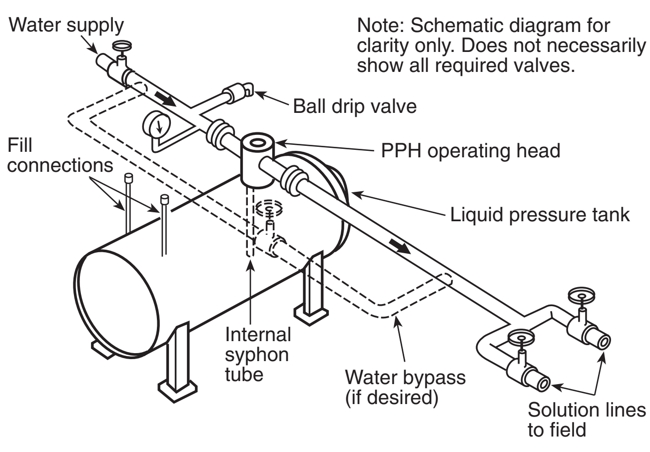


Figure A-1-4(k) Typical arrangement of pressure proportioning tank.

The limitations are the same as those listed above for the pressure proportioning tank except the system can be used for all types of concentrates.

(f) Pump Proportioner (Around-the-Pump Proportioner). This device consists of an eductor installed in a bypass line between the discharge and suction of a water pump. A small portion of the discharge of the pump flows through this eductor and draws the required quantity of air foam concentrate from a container, delivering the mixture to the pump suction. Variable capacity can be secured by the use of a manually controlled multiported metering valve. *[See Figure A-1-4(m).]*

A pump proportioner has the following limitations:

(a) The pressure on the water suction line at the pump must be essentially zero gauge pressure or must be on the vacuum side. A small positive pressure at the pump suction can cause a reduction in the quantity of concentrate educted or cause the flow of water back through the eductor into the concentrate container.

(b) The elevation of the bottom of the concentrate container should not be more than 6 ft (1.8 m) below the proportioner.

(c) The bypass stream to the proportioner uses from 10 gpm to 40 gpm (38 L/min to 151 L/min) of water depending on the size of the device and on the pump discharge pressure. This factor must be recognized in determining the net delivery of the water pump.

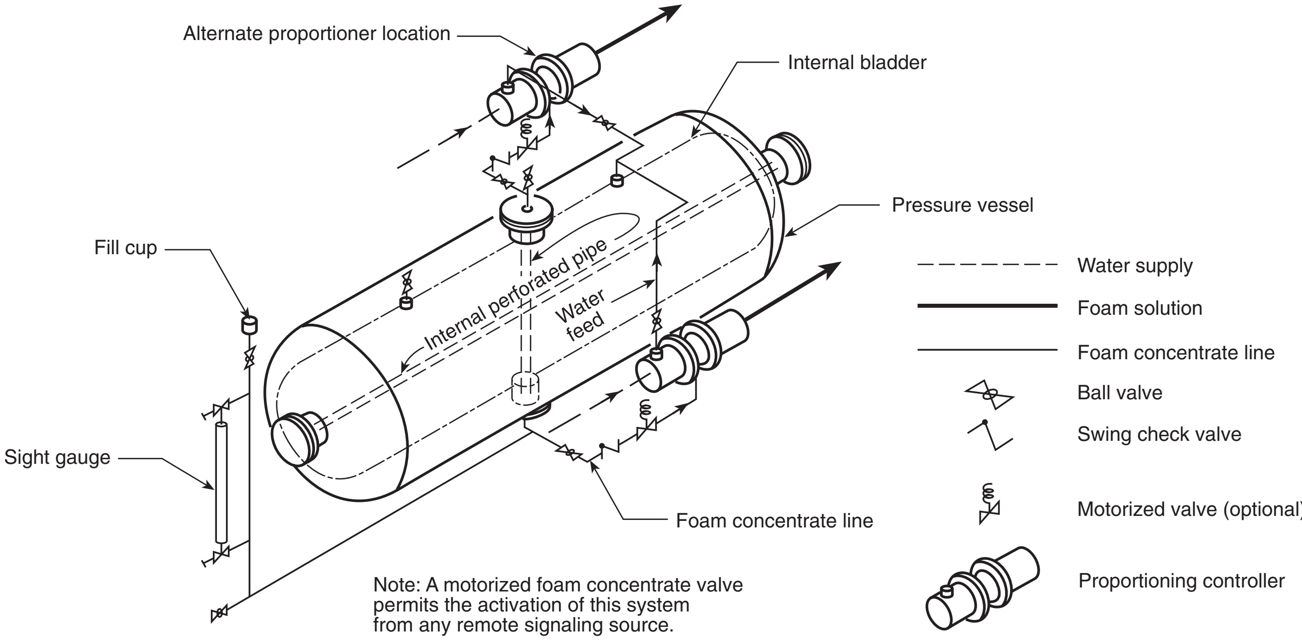


Figure A-1-4(l) Diaphragm (bladder) proportioning tank.

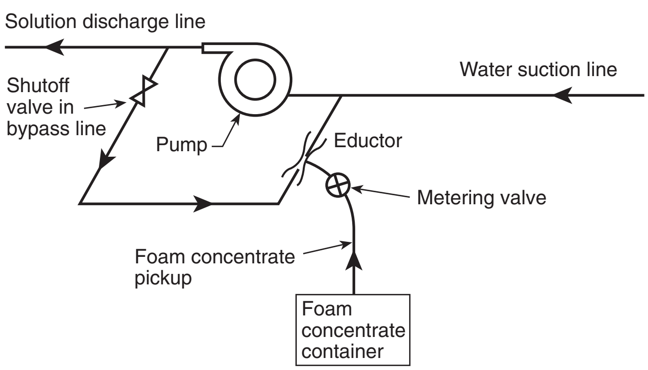


Figure A-1-4(m) Around-the-pump proportioner.

A-1-4 Type I Discharge Outlet. Approved Type I discharge outlets include the following:

(a) Porous tubes *[See Figure A-1-4(n).]*

(b) Foam troughs along the inside of tank wall *[See Figure A-1-4(o).]*

These outlets are designed to extinguish fire with a minimum of foam-producing materials. It should be noted, however, that Type I devices become Type II devices if they suffer mechanical damage.

Type I discharge outlets are generally considered obsolete because nearly all currently manufactured foams are suitable for use with Type II discharge outlets. *[See Figure A-1-4(p).]*

Porous Tube. The coarsely woven tube is rolled up in the foam chamber, one end being securely fastened to the foam supply line and the free end being stitched to close the opening at this point. When foam is admitted to the tube, the diaphragm closing the mouth of the chamber is broken out by the pressure of the tube against it. The tube then unrolls, dropping into the tank. The buoyancy of the foam causes the tube to rise to the surface and foam to flow through the interstices of the fabric directly onto the liquid surface.

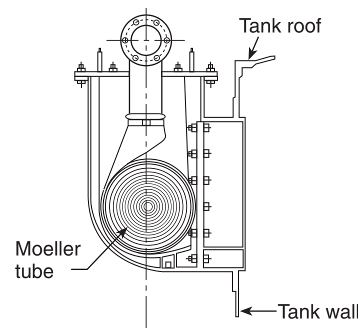


Figure A-1-4(n) Cross section of a Moeller tube chamber. Tube is designed to unroll and fall to oil level. Foam flows through interstices in tube.

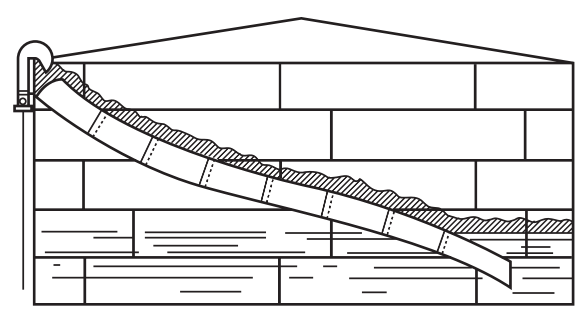


Figure A-1-4(o) Foam trough.

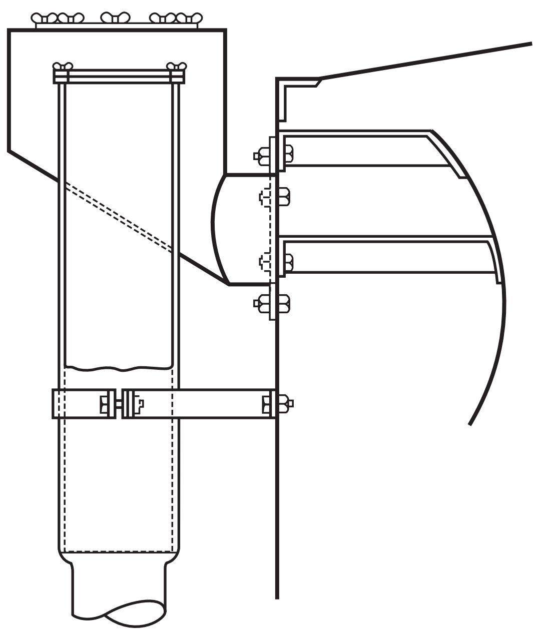


Figure A-1-4(p) Air foam chamber with Type II outlet.

Foam Trough. The trough shown schematically in Figure A-1-4(o) consists of sections of steel sheet formed into a chute securely attached to the inside of the tank wall so that it forms a descending spiral from the top of the tank to within 4 ft (1.2 m) of the bottom. *[See Figures A-1-4(q) and (r).]*

NOTE: One brace [1/2 in. (13 mm) plate, 12 in. (305 mm) long] should be provided at each shell course. This helps maintain the shell in place during the early stages of the fire and prevents buckling before cooling water is applied.

A-2-2.1.2 Additional water supplies are recommended for cooling the hot tank shell to assist the foam in sealing against the shell. Some foams are susceptible to breakdown and failure to seal as a result of heating the tank shell due to prolonged burning prior to agent discharge.

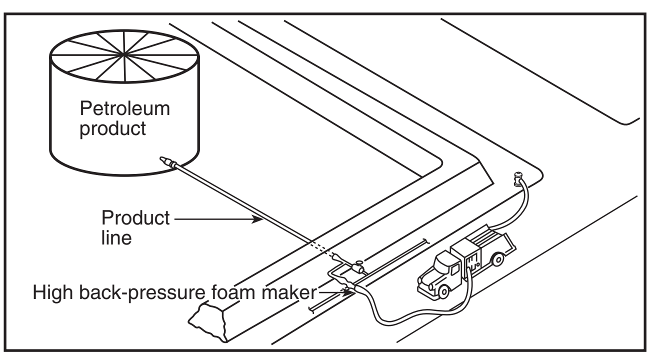


Figure A-1-4(q) Semifixed subsurface foam installation.

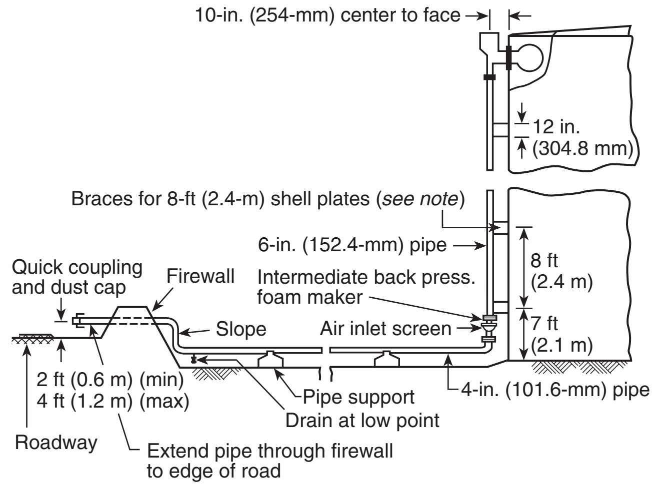


Figure A-1-4(r) Typical air foam piping for intermediate back-pressure foam system.

A-2-3.2.2 The level of concentrate in the storage tank should be monitored to ensure an adequate supply is available at all times.

The hazard requiring the largest foam solution flow rate does not necessarily dictate the total amount of foam concentrate required.

Example: A Class II product tank requiring a flow of 300-gpm (1136-L/min) foam solution for 30 minutes would require 270 gal (1022 L) of 3 percent concentrate. A Class I product tank requiring a flow of 250-gpm (946-L/min) foam solution for 55 minutes would require 412.5 gal (1563 L) of 3 percent concentration.

A-2-3.2.4.1 The storage temperature should be monitored to ensure that listed temperature limitations are not exceeded.

A-2-6 Foam concentrate pumps are generally of the positive displacement variety. Centrifugal pumps might not be suitable for use with foam concentrates exhibiting high-viscosity characteristics. The foam equipment manufacturer should be consulted for guidance. Provisions should be made for automatic shutoff of the foam concentrate pump after the concentrate supply is exhausted.

A-2-7.3.1 Welding is preferable where it can be done without introducing fire hazards.

A-2-7.5 A hazard area generally includes all areas within dikes and within 50 ft (15 m) of tanks without dikes. Other areas that should be considered hazard areas include the following:

(a) Locations more than 50 ft (15 m) from tanks without dikes, if the ground slope allows exposure from accidentally released flammable and combustible liquids
(b) Extensive manifold areas where flammable and combustible liquids might be released accidentally
(c) Other similar areas

The presence of flammable and combustible liquids within pipelines that do not possess the potential to release flammable and combustible liquids should not be considered as creating a hazard area.

Ball valves may be used for foam concentrate proportioning systems.

A-3-1 There have been cases reported where the application of foam through solid streams that were plunged into the flammable liquid have been believed to be the source of ignition of the ensuing fire. The ignitions have been attributed to static discharges resulting from splashing and turbulence. Therefore, any application of foam to an unignited flammable liquid should be as gentle as possible. Proper application methods with portable equipment may include a spray pattern or banking the foam stream off a backboard so that the foam flows gently onto the liquid surface. Also, properly designed fixed foam chambers on tanks could be expected to deliver the foam fairly gently and not cause a problem.

Covered (internal) floating roof tanks can experience two distinct types of fires: a full surface area fire (as a result of the floating roof sinking) or a seal fire. There have been few fires in double-deck or pontoon-type floating roof tanks where fixed-roofs and venting are designed in accordance with NFPA 30, *Flammable and Combustible Liquids Code*. Prior to selecting the method of protection, the type of fire that will serve as the basis for design should be defined.

A-3-2 These systems are used for the protection of outdoor process and storage tanks. They include the protection of such hazards in manufacturing plants as well as in large tank farms, oil refineries, and chemical plants. These systems usually are designed for manual operation but, in whole or in part, may be automatic in operation. Foam systems are the preferred protection for large outdoor tanks of flammable liquids. *(See Figure A-3-2.)*

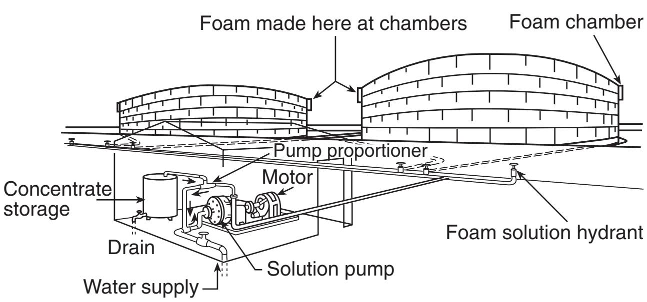


Figure A-3-2 Schematic arrangement of air foam protection for storage tanks.

A-3-2.1.3 Where the entire liquid surface has been involved, fires in tanks up to 150 ft (39 m) in diameter have been extinguished with large-capacity foam monitors. Depending on the fixed-roof tank outage and fire intensity, the updraft due to chimney effect may prevent sufficient foam from reaching the burning liquid surface to form a blanket. Foam should be applied continuously and evenly. Preferably, it should be directed against the inner tank shell so that it flows gently onto the burning liquid surface without undue submergence. This can be difficult to accomplish, as adverse winds, depending on velocity and direction, reduce the effectiveness of the foam stream. Fires in fixed-roof tanks with ruptured roofs that have only limited access for foam application are not easily extinguished by monitor application from ground level. Fixed foam monitors may be installed for protection of drum storage areas or diked areas.

A-3-2.2.3 Where protection is desired for hydrocarbons having a flash point above 200°F (93.3°C), a minimum discharge time of 35 minutes should be used.

A-3-2.2.4 When using some older types of alcohol-resistant foam concentrate, consideration should be given to solution transit time. Solution transit time (i.e., the elapsed time between injection of the foam concentrate into the water and the induction of air) may be limited, depending on the characteristics of the foam concentrate, the water temperature, and the nature of the hazard protected. The maximum solution transit time of each specific installation should be within the limits established by the manufacturer.

A-3-2.3.2.1 It is recommended that, for tanks greater than 200 ft (60 m) in diameter, at least one additional discharge outlet should be added for each additional 5000 ft^2 (465 m^2) of liquid surface or fractional part thereof. Since there has been limited experience with foam application to fires in fixed-roof tanks greater than 140 ft (42 m) in diameter, requirements for foam protection on such tanks are based on the extrapolation of data from successful extinguishments in smaller tanks. Tests have shown that foam can travel effectively across at least 100 ft (30 m) of burning liquid surface. On fixed-roof tanks of over 200-ft (60-m) diameter, subsurface injection can be used to reduce foam travel distances for tanks containing hydrocarbons only.

Unless subsurface foam injection is utilized, a properly sized flanged connection should be installed on all atmospheric pressure storage tanks, regardless of present intended service, to facilitate the future installation of an approved discharge outlet if a change in service should require such installation. Figures A-3-2.3.2.1(a) and (b) are typical fixed foam discharge outlets or foam chambers.

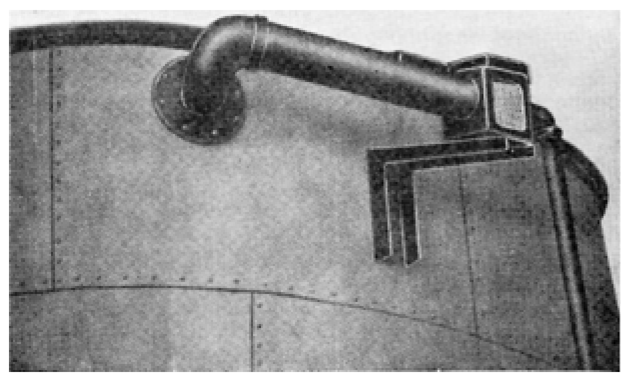


Figure A-3-2.3.2.1(a) Air foam maker in horizontal position at top of storage tank.

A-3-2.3.2.2 Where protection is desired for hydrocarbons having a flash point above 200°F (93.3°C), a minimum time of 15 minutes for Type I outlets and 25 minutes for Type II outlets should be used.

A-3-2.3.3 The system should be designed based on fighting a fire in one tank at a time. The rate of application for which the system is designed should be the rate computed for the protected tank considering both the liquid surface area and the type of flammable liquid stored.

Example: The property contains a 40-ft (12.2-m) diameter tank storing ethyl alcohol and 35-ft (10.7-m) diameter tank storing isopropyl ether.

The liquid surface area of a 40-ft (12.2-m) diameter tank equals 1257 ft^2 (116.8 m^2).

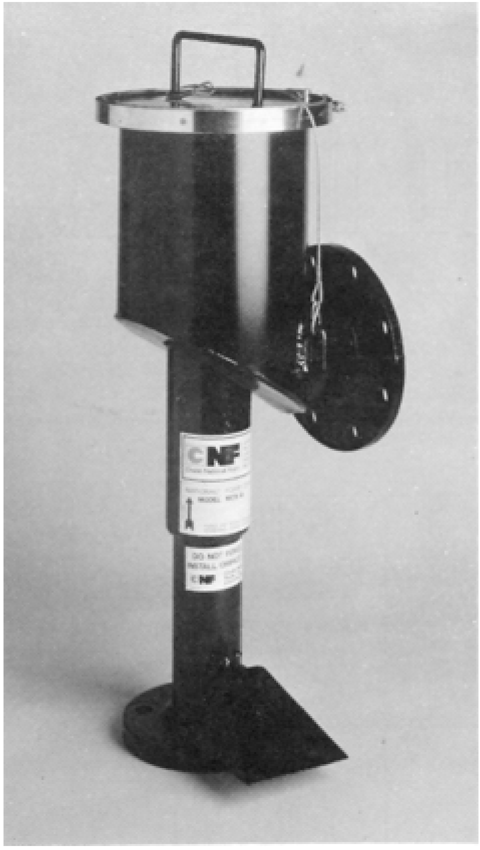


Figure A-3-2.3.2.1(b) Foam chamber and foam maker.

Assuming the solution rate for ethyl alcohol is 0.1 gpm/ft^2 (4.1 L/min·m^2), then 1257 gpm/ft^2 × 0.1 = 126 gpm (477 L/min).

The liquid surface area of a 35-ft (10.7-m) diameter tank equals 962 ft^2 (89.4 m^2).

Assuming the solution rate for isopropyl ether is 0.15 gpm/ft^2 (6.1 L/min·m^2) then 962 ft^2 × 0.15 gpm/ft^2 = 144 gpm.

For SI units: Solution Rate = 89.4 × 6.1 = 545 L/min

In this example, the smaller tanks storing the more volatile product require the higher foam-generating capacity. In applying this requirement, due consideration should be given to the future possibility of change to a more hazardous service requiring greater rates of application.

Unfinished solvents or those of technical grade may contain quantities of impurities or diluents. The proper rate of application for these, as well as for mixed solvents, should be selected with due regard to the foam-breaking properties of the mixture.

A-3-2.4.1 Experience with fuel storage tank fire fighting has shown that the main problems are operational (i.e., difficulty in delivering the foam relatively gently to the fuel surface at an application rate sufficient to effect extinguishment). A properly engineered and installed subsurface foam system offers the potential advantages of less chance for foam-generation equipment disruption as a result of an initial tank explosion or the presence of fire surrounding the tank, and the ability to conduct operations a safe distance from the tank. Thus, the opportunity for establishing and maintaining an adequate foam application rate is enhanced. The following guidelines regarding fire attack are recommended.

After necessary suction connections are made to the water supply and foam-maker connections are made to foam lines, foam pumping operations should be initiated simultaneously with opening of block valves permitting the start of foam flow to the tank. Solution pressure should be brought up to and maintained at design pressure.

When foam first reaches the burning liquid surface, there may be a momentary increase in intensity caused by the mechanical action of steam formation when the first foam contacts the heat of the fire.

Initial flame reduction and reduction of heat is then usually quite rapid, and gradual reduction in flame height and intensity will occur as the foam closes in against the tank shell and over the turbulent areas over foam injection points. If sufficient water supplies are available, cooling of the tank shell at and above the liquid level will enhance extinguishment and should be used. Care should be taken that water streams are not directed into the tank where they could disrupt the established foam blanket.

After the fire has been substantially extinguished by the foam, some fire may remain over the point of injection. With flash points below 100°F (37.8°C) (Class IB and Class IC liquids), the fire over the turbulent area will continue until it is adequately covered by foam. With gasoline or equivalent liquids, when fire remains only over the area of injection, intermittent injection should be used so that foam will retrogress over the area during the time foam injection is stopped. Depending on local circumstances, it may be possible to extinguish any residual flickers over the turbulent area with portable equipment rather than continue the relatively high rate of application to the whole tank.

If the tank contains a burning liquid capable of forming a heat wave, a slop-over may occur from either topside or subsurface injection of foam, especially if the tank has been burning for 10 minutes or longer. Slop-over can be controlled by intermittent foam injection or reduction in foam-maker inlet pressure until slop-over ceases. Once slop-over has subsided, and in the case of liquids that do not form a heat wave, the pump rate should be continuous.

Figures A-3-2.4.1(a) and (b) illustrate typical arrangements of semifixed subsurface systems.

A-3-2.4.2 Figures A-3-2.4.2(a) through (c) should be used to determine foam velocity.

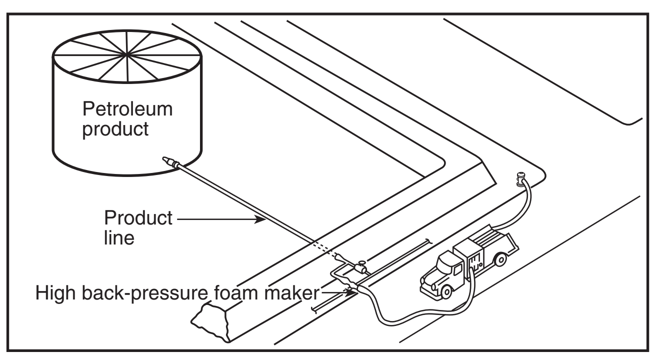


Figure A-3-2.4.1(a) Semifixed subsurface foam installation.

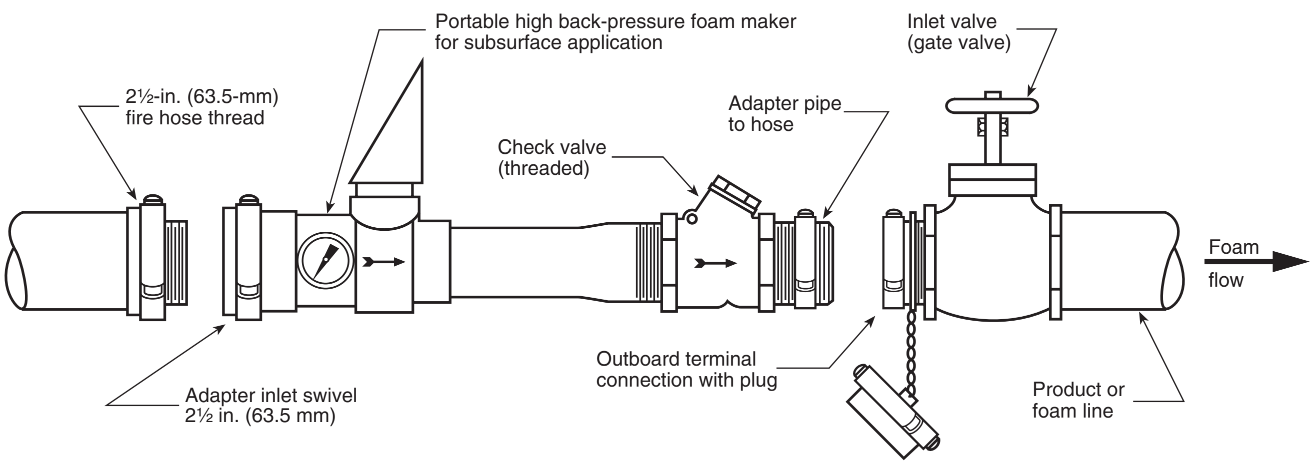


Figure A-3-2.4.1(b) Typical connection for portable high back-pressure foam maker for subsurface application in semifixed system.

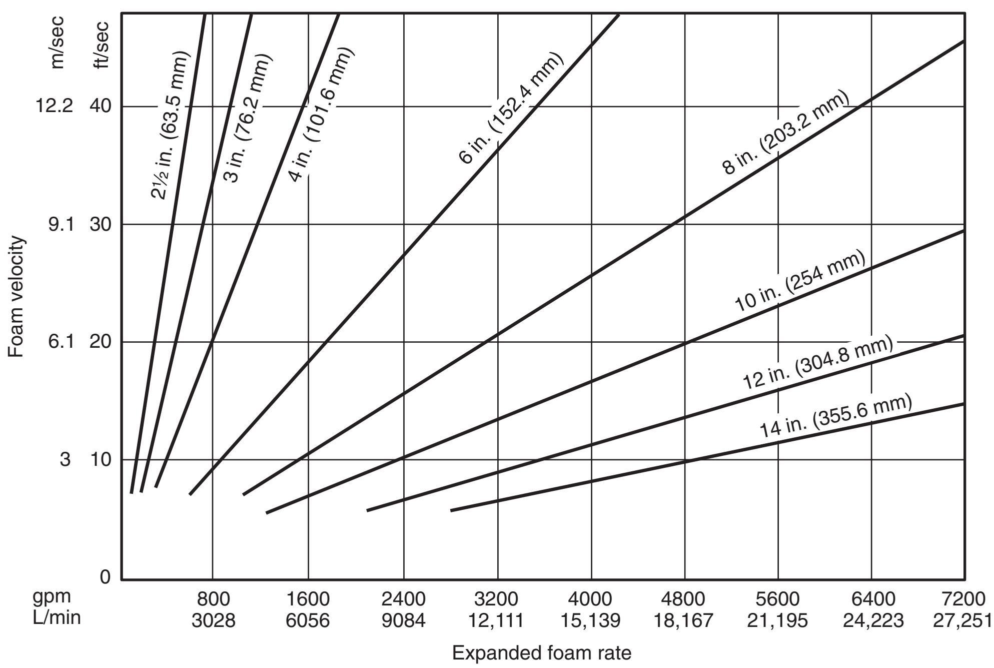


Figure A-3-2.4.2(a) Foam velocity vs. pipe size ($2\,^1/_2$ in., 3 in., 4 in., 6 in., 8 in., 10 in., 12 in., and 14 in.) — standard schedule 40 pipe.

Expanded foam velocity also may be calculated by using the following formulas:

$$\text{English velocity (ft/sec)} = \frac{\text{Expanded foam (gpm)}}{KA}$$

A = area of ID of the injection pipe (ft^2)

K = constant 449

gpm = gallons per minute

or

$$V = \frac{\text{gpm foam}}{d^2} \times 0.4085$$

where:
d = pipe ID (in.)

$$\text{Metric velocity (m/sec)} = \frac{\text{L/min foam}}{d^2} \times 21.22$$

where:
d = pipe ID (mm)

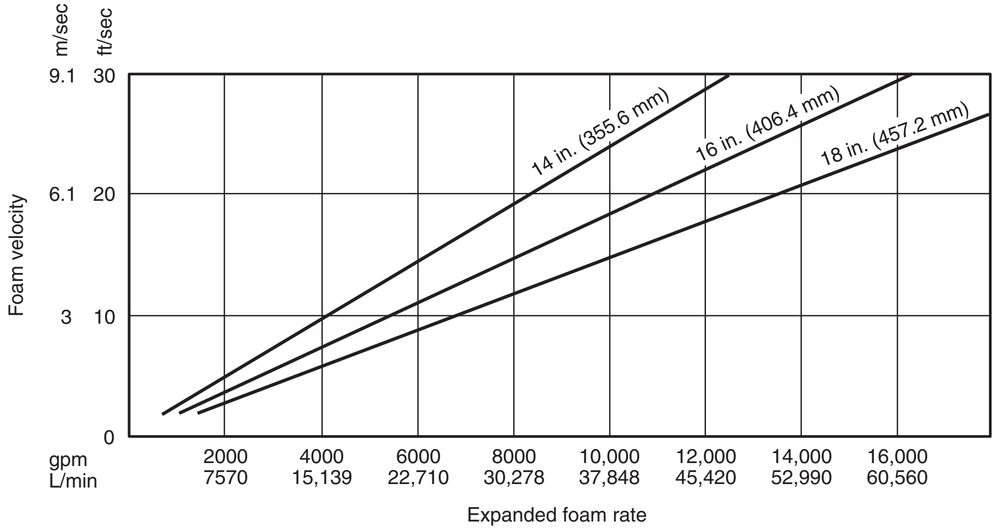


Figure A-3-2.4.2(b) Foam velocity vs. pipe size (14 in., 16 in., and 18 in.) — standard schedule 40 pipe.

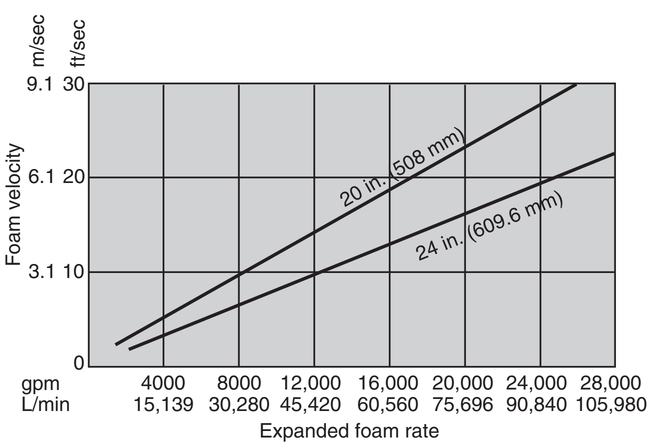


Figure A-3-2.4.2(c) Foam velocity vs. pipe size (20 in. and 24 in.) — standard schedule 40 pipe.

Figure A-3-2.4.2(d) illustrates optional arrangements for multiple subsurface discharge outlets.

A-3-2.4.2.1 Figure A-3-2.4.2.1 illustrates a typical foam inlet tank connection.

A-3-2.4.2.2 The back-pressure consists of the static head plus pipe friction losses between the foam maker and the foam inlet to the tank. The friction loss curves *[see Figures A-3-2.4.2.2(a) and (b)]* are based on a maximum foam expansion of 4, which is the value to be used for friction loss and inlet velocity calculations.

A-3-2.4.3.1 Optimum fluoroprotein foam, AFFF, and FFFP characteristics for subsurface injection purposes should have expansion ratios between 2 and 4. [*See Figures A-3-2.4.3.1(a) and (b).*]

A-3-2.5 This section describes the design criteria that is applicable to systems used to apply foam to the surface of fixed-roof (cone) storage tanks via a flexible hose rising from the base of the tank. Manufacturer recommendations should be followed for the design and installation of such systems. (For semisubsurface system arrangement, see Figure A-3-2.5.)

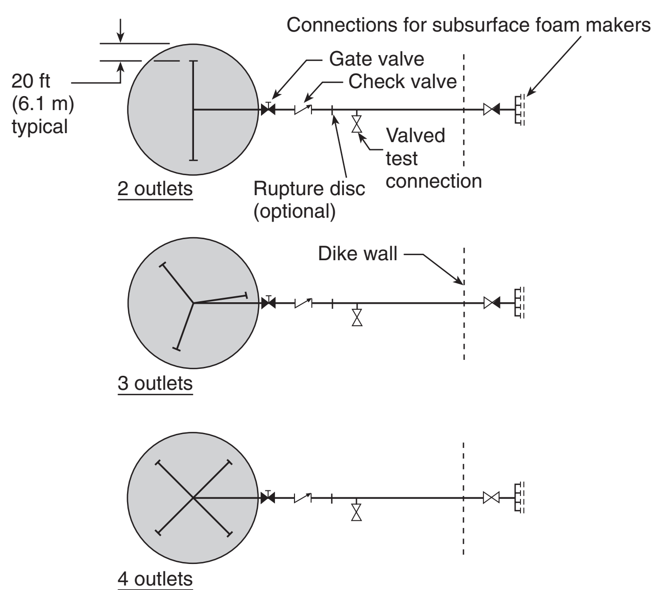


Figure A-3-2.4.2(d) Typical arrangement of semifixed subsurface system.

These systems are not considered appropriate for floating roof tanks with or without a fixed-roof because the floating roof prevents foam distribution. The flexible foam delivery hose is contained initially in a sealed housing and is connected to an external foam generator capable of working against the maximum product head. When operated, the hose is released from its housing, and the hose floats to the surface as a result of the buoyancy of the foam. Foam then discharges through the open end of the hose directly onto the liquid surface.

Consideration should be given to the following factors when selecting this type of system.

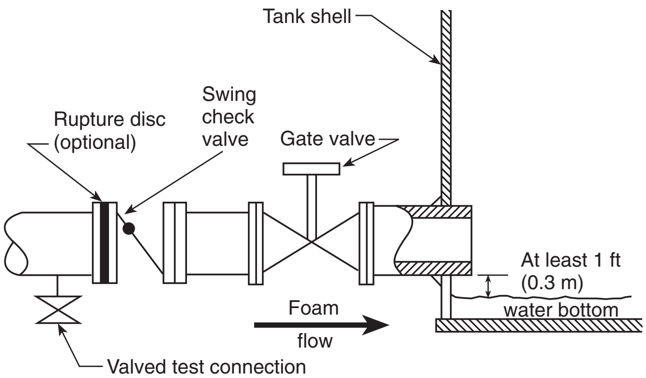


Figure A-3-2.4.2.1 Typical tank foam-maker discharge connection for subsurface injection.

(a) The total foam output should reach the surface of the burning liquid.

(b) With large tanks, the semisubsurface units can be arranged to produce an even distribution over the fuel surface.

(c) Any type of concentrate suitable for gentle surface application to the particular fuel may be used.

(d) Foam-generating equipment and operating personnel can be located at a distance from the fire.

(e) The system can be used for the protection of foam destructive liquids, provided the flexible hose is not affected by them.

(f) Certain high-viscosity fuels may not be suitable for protection by this type of system.

(g) There is no circulation of the cold fuel and, therefore, no assistance in extinguishment.

(h) The system may be difficult to check, test, and maintain.

(i) The high back-pressure foam generator has to produce foam at a pressure sufficient to overcome the head pressure of fuel as well as all friction losses in the foam pipework. Friction losses with foam differ from those with foam solution.

Design application rates and discharge times for hydrocarbons are typically the same as for Type II topside application systems [i.e., 0.1 gpm/ft^2 (4.1 L/min·m^2)]. Manufacturers should be consulted for appropriate application rates and design recommendations to be followed for protection of products requiring the use of alcohol-resistant foams.

Duration of discharge should be in accordance with Table A-3-2.5(a).

Semisubsurface foam units should be spaced equally, and the number of units should be in accordance with Table A-3-2.5(b).

Each semisubsurface unit should be secured by pipe supports suitable for the intended application and for mounting through the tank wall. To prevent leakage of the product, it is recommended that a check valve be fitted at the foam entry point adjacent to the tank wall for each unit.

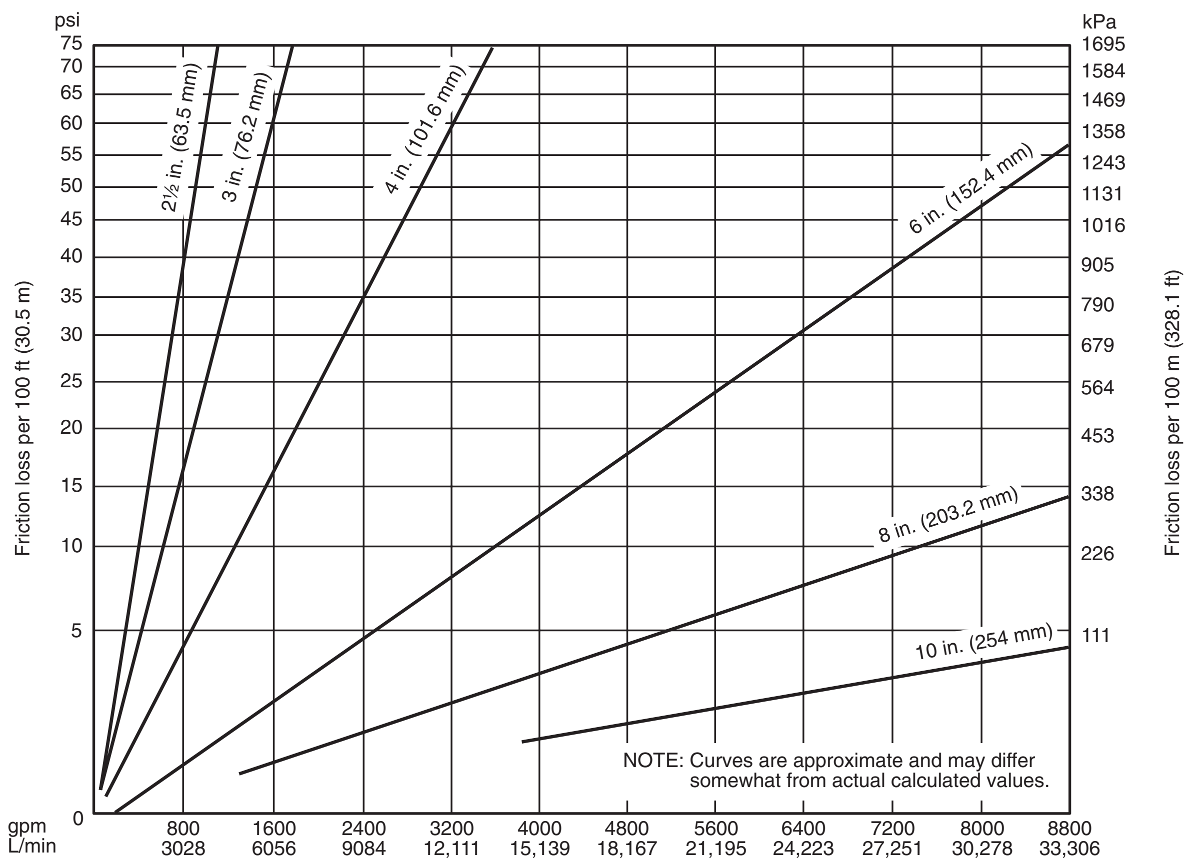


Figure A-3-2.4.2.2(a) Foam friction losses — 4 expansion (2 $^1/_2$ in., 3 in., 4 in., 6 in., 8 in., and 10 in.) — standard schedule 40 pipe.

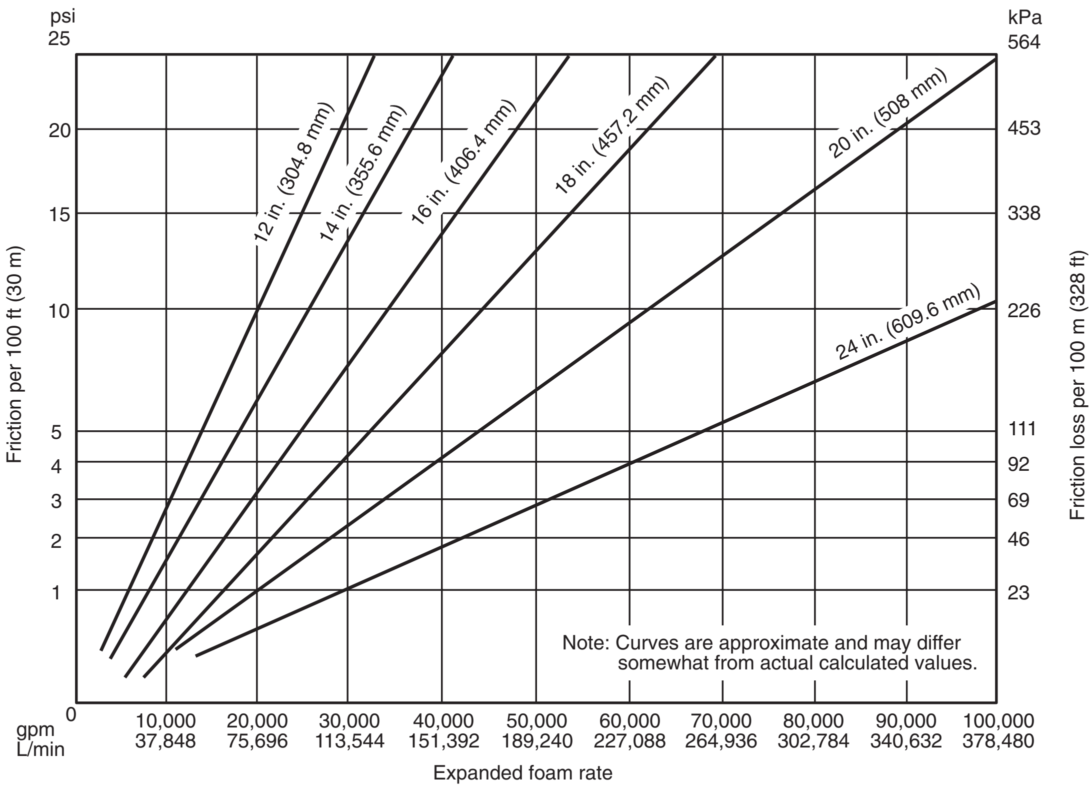


Figure A-3-2.4.2.2(b) Foam friction losses — 4 expansion (12 in., 14 in., 16 in., 18 in., 20 in., and 24 in.) — standard schedule 40 pipe.

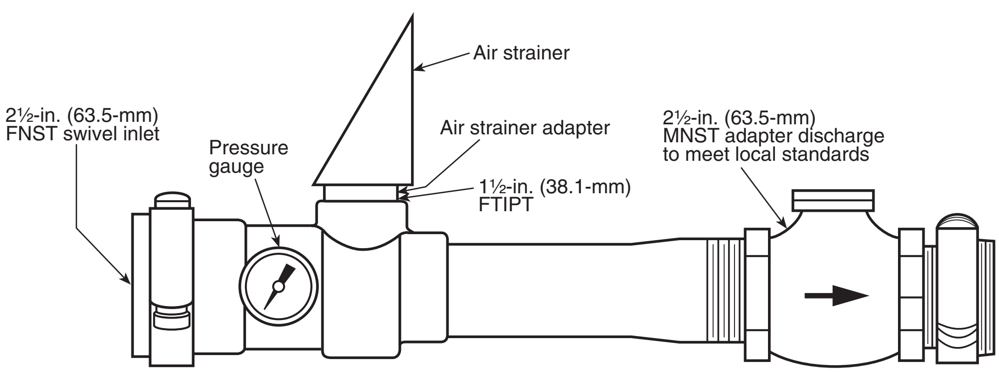


Figure A-3-2.4.3.1(a) Portable high back-pressure foam maker for semifixed systems.

A-3-3.1 Most fires in open-top floating roof tanks occur in the seal areas, and these fires can be extinguished with the foam systems described in Chapter 3. However, some fires involve the full surface area when the roof sinks. These fires are very infrequent and normally do not justify a fixed system to protect for this risk. Plans should be made to fight a full surface fire in a floating roof tank with portable or mobile equipment. Large capacity foam monitor nozzles with capacities up to 6000 gpm (22,712 L/min) are currently available. If foam-proportioning devices are not provided with the foam monitors, additional foam-proportioning trucks may be required through mutual aid. Generally, the number of foam-proportioning trucks available at any location is not sufficient to fight a sunken floating roof fire, and outside assistance is required.

Generally, the fire water systems available in floating roof tank areas are not designed to fight a full surface fire, so additional water is required. Therefore, relay pumping with municipal or mutual aid water pumpers may be required to obtain enough water for foam generation.

Another aspect to consider is the amount of foam concentrate available. The foam application rate of 0.16 gpm/ft^2 (6.5 L/min·m^2) of surface area listed in Chapter 3 may have to be increased for very large tanks. Therefore, the amount of foam concentrate available through mutual aid should be established prior to the fire. In some cases, it may be necessary to increase the on-site foam storage if mutual aid supplies are limited.

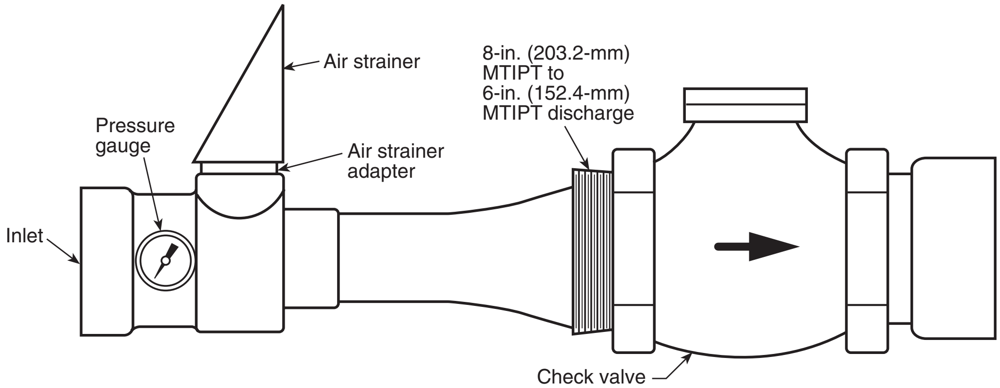


Figure A-3-2.4.3.1(b) Fixed high back-pressure foam maker for fixed systems.

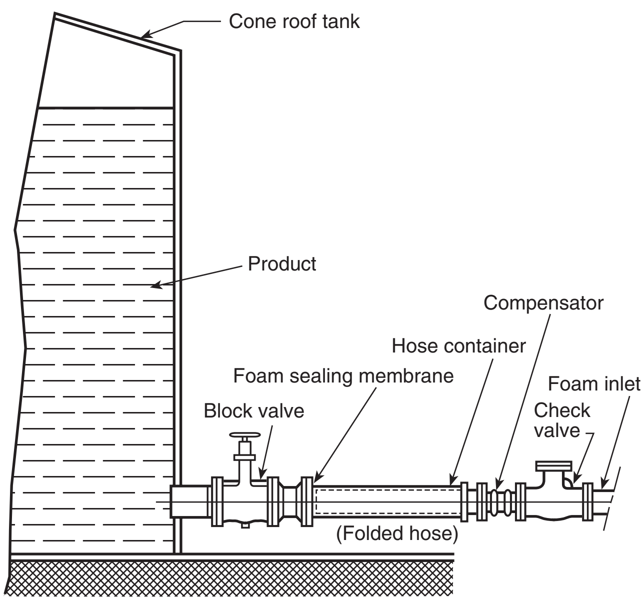


Figure A-3-2.5 Semisubsurface system arrangement.

If it is decided to fight a fire in a tank with a sunken roof instead of protecting the adjacent facilities and allowing a controlled burnout, the most important aspect is to plan ahead and hold simulated drills. Coordinating the efforts of many different organizations and various pumping operations required for fighting potentially catastrophic fires requires well-developed plans and plenty of practice.

A-3-3.3.1.1 Since all the discharge outlets are supplied from a common (ring) foam solution main, some vapor seal devices may not rupture due to pressure variations encountered as the system is activated. [*See Figures A-3-3.3.1.1(a) and (b).*]

A-3-3.4 Use of foam handlines for the extinguishment of seal fires should be limited to open-top floating roof tanks of less than 250 ft (76.2 m) in diameter. The following design information applies to foam handline protection methods.

(a) A foam dam should be installed in accordance with 3-3.3.3.

(b) To establish a safe base for operation at the top of the tank, a single fixed foam discharge outlet should be installed at the top of the stairs. This fixed foam discharge outlet is meant to provide coverage of the seal area for approximately 40 ft (12.2 m) on both sides of the top of the stairs.

(c) The fixed foam discharge outlet should be designed to discharge at least 50 gpm (189.3 L/min).

(d) To permit use of foam handlines from the windgirder, two 1.5-in. (38.1-mm) diameter valved hose connections should be provided at the top of the stairs in accordance with Figure A-3-3.4.

The windgirder should be provided with a railing for the safety of the fire fighters. (*See Figure A-3-3.4.*)

A-3-4.1.2.2 The hazard requiring the highest foam solution flow rate does not necessarily dictate the total amount of foam concentrate required.

Table A-3-2.5(a) Duration of Discharge for Semisubsurface Systems

Product Stored Foam	Type Minimum	Discharge Time (minutes)
Hydrocarbons with flash point below 100°F (37.8°C)	Protein, AFFF, fluoroprotein, FFFP, and alcohol-resistant AFFF or FFFP	55
Flash point at or above 100°F (37.8°C)	All foams	30
Liquids requiring alcohol-resistant foams	Alcohol-resistant foams	55

Table A-3-2.5(b) Minimum Number of Subsurface Units

Tank Diameter (ft)	Tank Diameter (m)	Minimum Number of Semisubsurface Units
Up to 80	Up to 24	1
Over 80 to 120	Over 24 to 36	2
Over 120 to 140	Over 36 to 42	3
Over 140 to 160	Over 42 to 48	4
Over 160 to 180	Over 48 to 54	5
Over 180 to 200	Over 54 to 60	6
Over 200	Over 60	6
		Plus 1 outlet for each additional 5000 ft^2 (465 m^2)

A-3-6 To minimize life and property loss, automation of foam systems protecting a truck loading rack should be taken into account. NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems,* states that "Automatic operation shall be provided and supplemented by auxiliary manual tripping means."

Exception: Manual operation only may be provided when acceptable to the authority having jurisdiction.

There are two methods of automating foam monitor systems for this application:

(a) Completely automatic detection and actuation. *(See applicable sections of NFPA 72, National Fire Alarm Code, for design criteria.)*

(b) Actuation by push-button stations or other means of manual release.

A-3-6.3.1 The proper choice of each monitor location is a very important factor in designing a foam monitor system. Traffic patterns, possible obstructions, wind conditions, and effective foam nozzle range affect the design. The appropriate monitors and nozzles should be located so that foam is applied to the entire protected area at the required application rate.

Consult the manufacturer of the monitor nozzle for specific performance criteria related to stream range and foam pattern, discharge capacity, and pressure requirements. Manufacturers also should be consulted to confirm applicable listings and/or approvals.

A-3-7 Generally, portable monitors or foam hose streams or both have been adequate in fighting spill fires in diked areas. In order to obtain maximum flexibility due to the uncertainty of location and the extent of a possible spill in process areas and tank farms, portable or trailer-mounted monitors are more practical than fixed foam systems in covering the area involved. The procedure for fighting diked area spill fires is to extinguish and secure one area and then move on to extinguish the next section within the dike. This technique should be continued until the complete dike area has been extinguished.

A-3-9 Auxiliary foam hose streams may be supplied directly from the main system protecting the tanks (e.g., centralized fixed pipe system) or may be provided by additional equipment. The supplementary hose stream requirements provided herein are not intended to protect against fires involving major fuel spills; rather, they are considered only as first aid–type protection for extinguishing or covering small spills involving areas in square feet (square meters) equal to those covered by about six times the rated capacity [in gpm (L/min)] of the nozzle.

Permanently installed foam hydrants, where used, should be located in the vicinity of the hazard protected and in safe and accessible locations. The location should be such that excessive lengths of hose are not required. Limitations on the length of hose that may be used depend on the pressure requirements of the foam nozzle.

A-4-1 The possibility and extent of damage by the agent should be evaluated when selecting any extinguishing system. In certain cases, such as tanks or containers of edible oils, cooking oils, or other food processing agents, or in other cases where contamination through the use of foam could increase the loss potential substantially, the authority having jurisdiction should be consulted regarding the type of extinguishing agent preferred.

A-5-1 Provisions should be made for automatic shutoff of the foam concentrate pump after the concentrate supply is exhausted.

A-5-3.4 Limited services controllers generally do not have a service disconnect means. In order to perform routine inspection and maintenance safely, it may be desirable to provide an external service disconnect. Special care must be taken to ensure the disconnect is not left in a position rendering the foam concentrate pump inoperable.

A-5-4.1.3(b) This riser can be welded to the tank by means of steel brace plates positioned perpendicular to the tank and centered on the riser pipe. *[See Figure A-1-4(p).]*

A-6-1 The provisions of this marine chapter were developed based on knowledge of practices of NFPA 11, *Standard for Low Expansion Foam,* SOLAS, the IBC Code, and USCG regulations and guidance. In order to harmonize the requirements of this chapter with the practices of these other standards, the values given in the metric conversions in Chapter 6 should be considered the required value.

A-6-1.1 Approvals of specialized foam equipment components are typically based on compliance with a standard equivalent to UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates.* Component review should include the following:

(a) Fire suppression effectiveness

(b) Reliability

(c) Mechanical strength

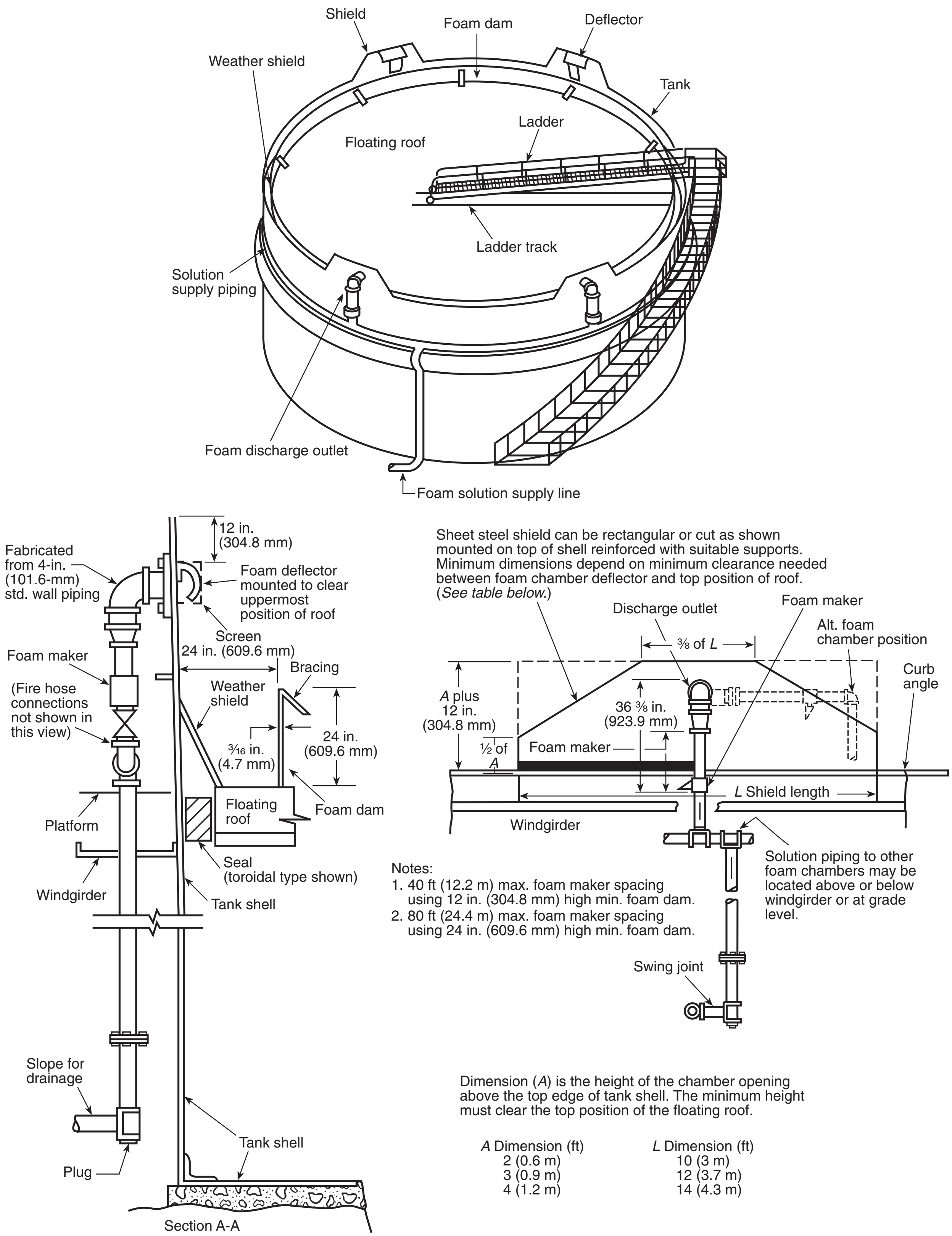


Figure A-3-3.3.1.1(a) Typical foam splash board for discharge devices mounted above the top of the shell.

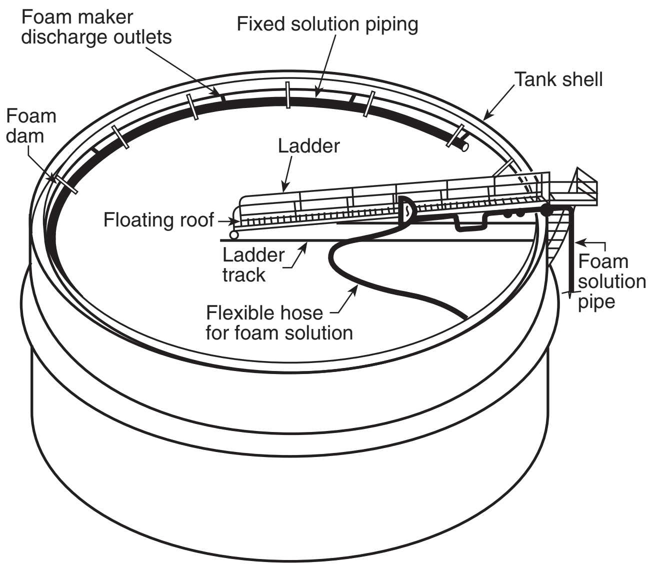


Figure A-3-3.3.1.1(b) Fixed foam discharge outlets mounted on the periphery of the floating roof.

(d) Corrosion resistance

(e) Material compatibility

(f) Proper operation

(g) Stress, shock, and impact

(h) Exposure to salt water, sunlight, temperature extremes, and other environmental elements

(i) Proportioning system test data (demonstrating acceptable injection rate over the intended flow range of the system)

(j) Foam stream range data (based on still air testing with monitor and nozzle combinations)

(k) Foam quality test data (demonstrating satisfactory performance corresponding to small scale fire test nozzle foam quality)

Quality control of specialty foam proportioning and application equipment as well as foam concentrates should be achieved through a listing program that includes a manufacturing follow-up service, independent certification of the production process to ISO 9001, *Quality Systems — Model for Quality Assurance in Design, Development, Production, Installation, and Servicing,* and ISO 9002, *Quality Systems — Model for Quality Assurance in Production, Installation, and Servicing,* or a similar quality control program approved by the authority having jurisdiction.

A-6-1.2.2 Foams for polar solvents are first tested for hydrocarbon performance using a test derived from Federal Specification O-F-555C that was published from 1969 through 1990. The foams are further tested for polar solvent system application on the basis of 50 ft^2 (4.6 m^2) fire test performance in accordance with UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates*. Approved manufacturer's deck system design application rates and operating times incorporate design factors that are applied to the fire test application rates and times.

A-6-2.1 This system is intended to supplement, not replace, any required total flooding machinery space fire suppression system. Foam systems comprising a portion of required primary machinery space protection may require longer application times.

A-6-3.1 Although shipboard foam systems share many similarities with tank farm foam systems on land, there are important differences between shipboard and land-based fire protection. These differences, identified in (a) through (o), result in foam system designs and arrangements that differ from systems used in what may appear to be similar land-based hazards.

(a) Foam fire tests of the type described in Appendix F are very severe.

(b) There is limited data regarding use of systems meeting USCG or IMO requirements on actual fires.

(c) There is little or no separation between tanks.

(d) The vessel may be widely separated from other hazards or may be alongside another vessel or a terminal.

(e) The vessel may not have access to immediate fire-fighting assistance.

(f) Fires resulting from catastrophic events, such as explosions and collisions, historically are beyond the onboard fire-fighting capabilities of the involved vessels necessitating use of outside fire-fighting assistance. Many large fires have taken several days to extinguish.

(g) The number of fire-fighting personnel is limited to the available crew.

(h) Fires not substantially controlled within the first 20 minutes may exceed the capability of the crew and the onboard system.

(i) Ships are subject to rolling, pitching, and yawing, which can cause sloshing of the burning liquid and reduced performance of the foam blanket.

(j) Application of foam to the fire is likely to be much faster than on land because the deck foam system is in place and can be activated simply by starting a pump and opening certain valves. There is little or no set-up time.

(k) Tank fires don't seem to occur unless preceded by an explosion.

(l) Explosions can cause substantial damage to foam systems. They can have unpredictable results on the vessel structure including bending deck plating in such a way so as to obstruct foam application. They may also cause involvement of any number of tanks or spaces.

(m) Most tankers use inert gas systems to reduce vapor spaces above cargo tanks to less than 8 percent oxygen thereby reducing the likelihood of an explosion.

(n) Ships pay the cost of transporting their fire suppression systems on every voyage.

(o) There is a finite amount of space on each ship design. Tanker deck foam monitors are located at or above the elevation of top of the tank as contrasted with typical tank farm arrangements where monitors must project foam up and over the rim of a tank.

A-6-3.2.2 Color coding the valves aids in identification. For example, all valves that are to be opened may be painted some distinctive color.

A-6-3.3 A fire main system may provide other services in addition to fire protection. Other services, which could be left operational during a fire, need to be included in calculations.

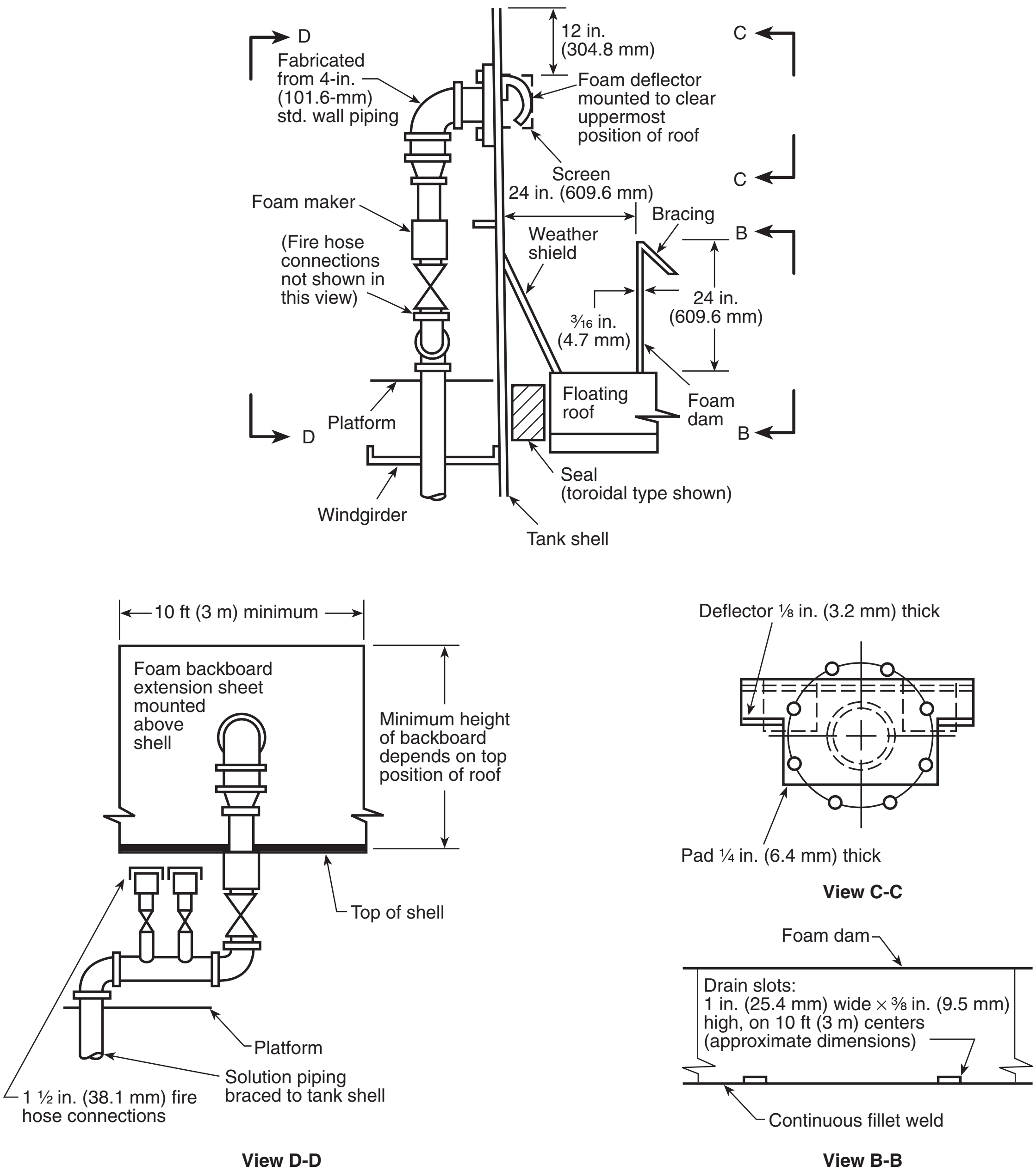


Figure A-3-3.4 Typical installation of foam handlines for seal area fire protection.

A-6-3.4

(a) *Differences Between this Section and SOLAS or the IBC Code.* The application rates prescribed in this section for hydrocarbon fuels are higher than the rates given in the International Maritime Organization's International Convention for the Safety of Life at Sea (SOLAS) Chapter 212 Regulation 61 as follows:

1. Deck spills. This section requires 0.16 gpm/ft^2 (6.5 L/min·m^2) applied over the 10 percent of the cargo block versus 0.147 gpm/ft^2 (5.98 L/min·m^2) in SOLAS. This difference is based on a long history of fire extinguishment experience using 0.16 gpm/ft^2 (6.5 L/min·m^2). It is also understood that the value 0.16 gpm/ft^2 (6.5 L/min·m^2) is generally regarded as the minimum foam application rate for industrial hazards and reflects the minimum application rate on the fuel surface, not at the discharge device. Thus, loss of foam due to wind, obstructions, and so forth, should be compensated for to provide 0.16 gpm/ft^2 (6.5 L/min·m^2) on the liquid surface.
2. Single largest tank. This section requires 0.24 gpm/ft^2 (9.77 L/min·m^2) over the single largest hydrocarbon tank versus 0.147 gpm/ft^2 (5.98 L/min·m^2) in SOLAS. This difference is based on the need to deliver a minimum of 0.16 gpm/ft^2 (6.5 L/min·m^2) onto the surface of the burning fuel and takes into consideration the impact of wind, evaporation, and thermal updrafts. This value is consistent with recent experience with the extinguishment of shore-based

storage tanks using mobile foam equipment similar to the monitors used in deck foam systems.

3. Polar solvents. The International Bulk Chemical Code (IBC Code) provides two design methods. The first method requires a foam application rate of 0.5 gpm/ft^2 (20.3 L/min·m^2) without restriction to the type of chemicals that may be carried or where on the ship's cargo block they may be carried. The second method allows arrangements with application rates lower than 0.5 gpm/ft^2 (20.3 L/min·m^2). This method is allowed if the country where the vessel is registered has determined through fire tests that the actual foam application rate at each cargo tank is adequate for the chemicals carried in that tank. The design practices given in this section comply with the second method of the IBC Code. (Reference 1994 IBC Code Regulation 11.3.13.)

(b) *Reliance on Monitor Application.* It is recognized that for land applications this standard generally restricts monitor application of foam according to tank diameter and surface area. A significant difference between monitor applications on land and those on tank ships is that the monitors on tank ships are located at or above the elevation of the top of the tank. Therefore, shipboard systems do not suffer losses of agent associated with long throws getting foam up and over tank rims. Additionally, tank ship monitors can be placed in operation immediately after an incident as there is little or no set-up time and each monitor is required to be sized to deliver at least 50 percent of the required foam application rate.

(c) *Design Factors.* The application rates given in this section incorporate design factors that allow the results of small scale fire tests to be applied to full scale fires. Design factors include scaling factors that allow the results of small scale tests to be extrapolated to large scale. In addition, compensation factors are included to account for losses expected from wind, thermal updraft, stream break-up, plunging, and other adverse conditions. The application rates and incorporated design factors are shown in Table A-6-3.4.

(d) *Monitor Design Philosophy.* The design philosophy given in this standard reflects that outlined in NVIC 11-82, *Deck Foam Systems for Polar Solvents.* NVIC 11-82 assumes that the minimum single tank design application rate will be 0.16 gpm/ft^2 (6.5 L/min·m^2). It then allows monitors to be calculated using 45 percent of the single tank rate. SOLAS and the IBC Code require the monitor to be calculated at 50 percent of the single tank rate. However, SOLAS starts with a single tank application rate of 0.147 gpm/ft^2 (6 L/min·m^2) so that 50 percent of that rate exactly equals 0.0735 gpm/ft^2 (3 L/min·m^2), which is 45 percent of the NVIC 11-82 minimum application rate of 0.16 gpm/ft^2 (6.5 L/min·m^2). The IBC Code also requires monitors to be sized for 50 percent of the single tank flow rate.

A-6-3.5.1 Foam application durations given in this section are generally lower than those given in other sections of this standard. This difference is based on historically quick deployment of marine deck foam systems and also takes into account all of the factors listed in A-6-3.1.

A-6-3.5.3 The flow rates during an actual system discharge will generally be greater than the minimum rates calculated during system design because pumps, eductors, and nozzles are typically not available in sizes for the exact minimum flow rate needed. Therefore, this equipment will typically be selected at the next larger commercially available size. Because the system, built of components larger than the minimum required, will flow foam at a rate greater than the minimum calculated, the foam concentrate will be used faster than the minimum usage rate. Since the concentrate will be used at a rate higher than the minimum, the storage quantity should be sized to provide the actual delivery rate during the entire required discharge duration.

A-6-4 Although foam handlines are required for supplementary protection, it is not practical to rely on handlines for primary fire fighting. Therefore, all required foam application must be provided by monitors that cover the protected area.

A-6-9.2 Pipe should be uniformly supported to prevent movement due to gravity, heaving of the vessel in heavy weather, impact, and water hammer. Pipe should be supported by steel members.

A-6-9.3 Deck foam system piping is not a substitute for any portion of a vessel's fire main system. Conversely, the requirement is intended to clarify that foam injected into the ship's fire main is not a substitute for a dedicated foam system on the weather deck. The requirement is not intended to prevent the proportioning of foam into a ship's fire main. Such a capability may be of great value during a machinery space fire or any other fire involving flammable liquids.

Table A-6-3.4 Foam Application Rates

Fuel	Scenario	100 ft^2 Test Fire	Scaling Design Factor	Fuel Surface Application Rate	Compensation Design Factor	Required Application Rate
Hydrocarbon	Deck spill	0.06 gpm/ft^2 (2.4 L/min·m^2)	2.67 (8/3)	0.16 gpm/ft^2 (6.5 L/min·m^2)	1.0	0.16 gpm/ft^2 (6.5 L/min·m^2)
Hydrocarbon	Single largest tank	0.06 gpm/ft^2 (2.4 L/min·m^2)	2.67	0.16 gpm/ft^2 (6.5 L/min·m^2)	1.5	0.24 gpm/ft^2 (9.8 L/min·m^2)
Polar	Deck spill	Rate ≥0.06 gpm/ft^2 (2.4 L/min·m^2) as determined by test	2.67	Test rate × 2.67 ≥ 0.16 gpm/ft^2 (6.5 L/min·m^2)	1.0	≥0.16 gpm/ft^2 (6.5 L/min·m^2)
Polar	Single largest tank	Rate ≥0.06 gpm/ft^2 (2.4 L/min·m^2) as determined by test	2.67	Test rate × 2.67 ≥ 0.16 gpm/ft^2 (6.5 L/min·m^2)	1.5	≥0.24 gpm/ft^2 (9.8 L/min·m^2)

A-6-9.4 The system should be arranged to prevent ice from forming in any portion of the system. Sloped piping and manual low point drains are considered to meet the requirement that the system be self-draining.

A-6-10.1 Refer to the environmental report (Appendix E) for further information related to environmental issues when performing system discharge tests.

A-6-11.1.1 The primary foam concentrate tank is the tank containing the supply calculated to satisfy the requirements of 6-3.4 and 6-3.5. The location of emergency back-up supplies and supplies of concentrate for refilling the primary tank are not subject to the storage location restrictions of 6-11.2. However, all foam concentrate storage is subject to other provisions of this chapter such as those regarding prevention of freezing and foam compatibility.

A-6-11.2.1 Corrosion occurs at the air/foam/tank interface. Therefore, the small surface area of this interface in the tank dome results in less corrosion than if the interface occurs in the body of the tank. Tank domes are also used to reduce the available free surface subject to sloshing. Sloshing causes premature foaming and adversely affects foam proportioning. In addition, sloshing can cause cracking or other damage to the tank. Also foam evaporates so the use of a pressure vacuum (PV) vent is necessary. A PV vent allows air to enter the tank as liquid is discharged, allows air to leave the tank as liquid fills the tank, and allows the PV valve to prevent evaporation of the concentrate.

A-6-12.1 Examples of acceptable arrangements are shown in Figures A-1-4(i) and A-1-4(j). Consideration should be given to the need for spare or redundant critical equipment.

A-6-12.2 Where foam concentrate pumps are flushed with sea water, the pump should be constructed of materials suitable for use with sea water.

A-6-12.3 Portions of TP 127 are generally considered equivalent to IEEE 45, *Recommended Practice for Electric Installations on Shipboard*.

A-6-13.4 Some pipe joint sealants are soluble in foam concentrate.

A-7-3 Acceptance Tests.

(a) A foam system will extinguish a flammable liquid fire if operated within the proper ranges of solution pressure and concentration and at sufficient discharge density per square feet (square meters) of protected surface. The acceptance test of a foam system should ascertain the following:

1. All foam-producing devices are operating at system design pressure and at system design foam solution concentration.
2. Laboratory-type tests have been conducted, where necessary, to determine that water quality and foam liquid are compatible.

(b) The following data are considered essential to the evaluation of foam system performance:

1. Static water pressure
2. Stabilized flowing water pressure at both the control valve and a remote reference point in the system
3. Rate of consumption of foam concentrate

The concentration of foam solution should be determined. The rate of solution discharge may be computed from hydraulic calculations utilizing recorded inlet or end-of-system operating pressure or both. The foam liquid concentrate consumption rate may be calculated by timing a given displacement from the storage tank or by refractometric or conductivity means. The calculated concentration and the foam solution pressure should be within the operating limit recommended by the manufacturer.

A-7-3.3 The rate of concentrate consumption may be measured by timing a given displacement from the foam concentrate storage tank but only in systems where the storage tank is small enough and the test run time is long enough so that this can be accomplished with reasonable accuracy.

A-7-3.3.1(b) The rate of concentrate flow can be measured by timing a given displacement from the storage tank. Solution concentration can be measured by either refractometric or conductivity means *(see Section C-2)*, or it may be calculated from solution and concentrate flow rates. Solution flow rates can be calculated by utilizing recorded inlet or end-of-system operating pressures or both.

A-8-1.1 Flushing of the concentrate pump may be necessary at periodic intervals or following complete discharge of concentrate.

Appendix B Storage Tank Protection Summary

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

See Table B-1.

Appendix C Tests for the Physical Properties of Foam

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

C-1 Procedures for Measuring Expansion and Drainage Rates of Foams.

C-1.1 Foam Sampling. The object of foam sampling is to obtain a sample of foam typical of that to be applied to burning surfaces under anticipated fire conditions. Because foam properties are readily susceptible to modification through the use of improper techniques, it is extremely important that the prescribed procedures be followed.

A collector is designed chiefly to facilitate the rapid collection of foam from low-density patterns. In the interest of standardization, it is used also for all sampling, except where pressure-produced foam samples are being drawn from a line tap. A backboard is inclined at a 45-degree angle suitable for use with vertical streams falling from overhead applicators as well as horizontally directed streams. [*See Figures C-1.1(a) and (b).*]

The standard container is 7.9 in. (200.67 mm) deep and 3.9 in. (99.06 mm) inside diameter (1600 ml) and preferably made of $^{1}/_{16}$-in. (1.55-mm) thick aluminum or brass. The bottom is sloped to the center where a $^{1}/_{4}$-in. (6.4-mm) drain fitted with a $^{1}/_{4}$-in. (6.4-mm) valve is provided to draw off the foam solution. [*See Figure C-1.1(b).*]

Table B-1 Storage Tank Protection Summary

	Fixed-Roof (Cone) Tanks and Pan-Type Floating Roof Tanks			Applicable Floating Roof Tanks (Open-Top or Covered) Annular Seal Area
Top Side Foam Application				
Number of foam outlets required	Up to 80 ft (24.4 m) dia.	1 foam chamber		1 for each 40 ft (12.2 m) of circumference with a 12 in. (304.8 mm) high foam dam
	81 to 120 ft (24.7 to 36.6 m) dia.	2 foam chambers		
	121 to 140 ft (36.9 to 42.7 m) dia.	3 foam chambers		1 for each 80 ft (24.4 m) of circumference with a 24 in. (609.6 mm) high foam dam
	141 to 160 ft (43 to 48.8 m) dia.	4 foam chambers		
	161 to 180 ft (49.1 to 54.9 m) dia.	5 foam chambers		*(See 3-3.3.1 and Section 3-4)*
	181 to 200 ft (55.2 to 61 m) dia.	6 foam chambers		
	Over 201 ft (61.3 m) dia. *(See Table 3-2.3.2.1)*	1 additional for each 5000 ft^2		
Hydrocarbon application rates	0.10 gpm/ft^2 (4.1 L/min·m^2) of liquid surface *(See Table 3-2.3.2.2)*			0.30 gpm/ft^2 (12.2 L/min·m^2) of annular ring area, above seal, between tank wall and foam dam *(See Section 3-3)*
Polar solvent rates	See Manufacturer's Approval Report			Not covered by NFPA 11
Hydrocarbon discharge times		Type I	Type II	
	Flash point 100°F to 140°F (37.8°C to 60°C)	20 min	30 min	20 min
	Flash point below 100°F (37.8°C)	30 min	55 min	
	Crude petroleum	30 min	55 min	*(See Section 3.3)*
Polar solvents	Type I	30 min		Not covered by NFPA 11
	Type II	55 min		
Foam Outlets Under Floating Roof Tank Seals or Metal Secondary Seal				
Number required	Not applicable			Mechanical shoe seal 1 — For each 130 ft (39.6 m) of tank circumference (no foam dam required) Tube Seal—Over 6 in. (152 mm) from top of seal to top of pontoon with foam outlets under metal weather shield or secondary seal 1 — For each 60 ft (18.3 m) of tank circumference (no foam dam required) Tube Seal—Less than 6 in. (152 mm) from top of seal to top of pontoon with foam outlets under metal weather shield or secondary seal 1 — For each 60 ft (18.3 m) of tank circumference [foam dam at least 12 in. (305 mm) high required] *(See 3-3.3.3)*
Hydrocarbon application rates	Not applicable			Top-of-seal protection with foam dam at 0.30 gpm/ft^2 (12.2 L/min·m^2) of annular ring area. All below-the-seal with or without foam dam at 0.50 gpm/ft^2 (20.4 L/min·m^2)
Discharge times	Not applicable			20 min — with foam dam or under metal weather shield or secondary seal
Polar solvents	Not applicable			Not covered by NFPA 11
Foam Handlines and Monitors for Tank Protection				
Size of tank	Monitors for tanks up to 60 ft (18.3 m) in diameter			Monitors not recommended
	Hand hoselines for tanks less than 30 ft (9.2 m) in diameter and less than 20 ft (6.1 m) high			Handlines are suitable for extinguishment of rim fires in open-top floating roof tanks
	(See 3-2.2.1)			(See 3-3.4)
Hydrocarbon application rates	0.16 gpm/ft^2 (6.5 L/min·m^2)			0.16 gpm/ft^2 (6.5 L/min·m^2)
	(See 3-2.2.2, 3-2.2.3, and 3-2.2.4)			For rim fires in open-top floating roof tanks *(See 3-2.2.2, 3-2.2.3, and 3-2.2.4)*
Discharge times	Flash point below 100°F (37.8°C)		65 min	Use same times as for open-top floating roof tank rim fires
	Flash point 100°F to 140°F (37.8 to 60°C)		50 min	
	Crude oil *(See 3-2.2.3)*		65 min	

Table B-1 Storage Tank Protection Summary *(Continued)*

	Fixed-Roof (Cone) Tanks and Pan-Type Floating Roof Tanks		Applicable Floating Roof Tanks (Open-Top or Covered) Annular Seal Area
Subsurface Application Outlets			
Number required	Same as table for foam chambers. See above. *(See 3-2.4.1, 3-2.4.2, and 3-2.4.2.1.)*		Not recommended
Hydrocarbon application rates	Minimum 0.1 gpm/ft^2 (4.1 L/min·m^2) of liquid surface Foam velocity from outlet shall not exceed 10 ft/sec (3.05 m/sec) for Class 1B liquids or 20 ft/sec (6.1 m/sec) for all other liquids		Not recommended
	Maximum 0.2 gpm/ft^2 (8.2 L/min·m^2)		
	(See 3-2.4.2 and 3-2.4.3)		
Discharge times	Flash point 100°F (37.8°C) to 140°F (60°C)	30 min	Not recommended
	Flash point below 100°F (37.8°C)	55 min	
	Crude petroleum *(See 3-2.4.3)*	55 min	
Polar solvents	Not recommended		Not recommended

For SI units: 1 gpm/ft^2 = 40.746 L/min·m^2; 1 ft = 0.305 m;
1 ft^2 = 0.0929 m^2; 1 in. = 25.4 mm; °C = °F –32/1.8; 1 ft/sec = 0.0305 m/sec

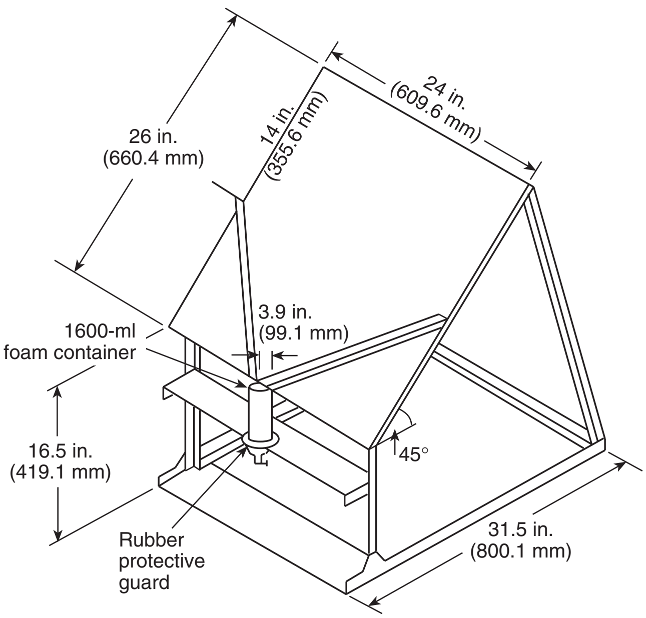


Figure C-1.1(a) Foam sample collector.

C-1.2 Turrets or Handline Nozzles. (It is presumed that the turret or nozzle is capable of movement during operation to facilitate collection of the sample.) It is important that the foam samples taken for analysis represent as nearly as possible the foam reaching the burning surface in a normal fire-fighting procedure. With adjustable stream devices, samples should be taken from both the straight stream position and the fully dispersed position and possibly from other intermediate positions.

Initially, the collector should be placed at the proper distance from the nozzle to serve as the center of the ground pattern. The nozzle or turret should be placed in operation while it is directed off to one side of the collector. After the pressure and operation have become stabilized, the stream is swung over to center on the collector. When a sufficient foam volume has accumulated to fill the sample containers, usually within only a few seconds, a stopwatch is started for each of the two samples in order to provide the "zero" time for the drainage test described later. Immediately, the nozzle is turned away from the collector, the sample containers removed, and the top struck off with a straight edge. After all foam has been wiped off from the outside of the container, the sample is ready for analysis.

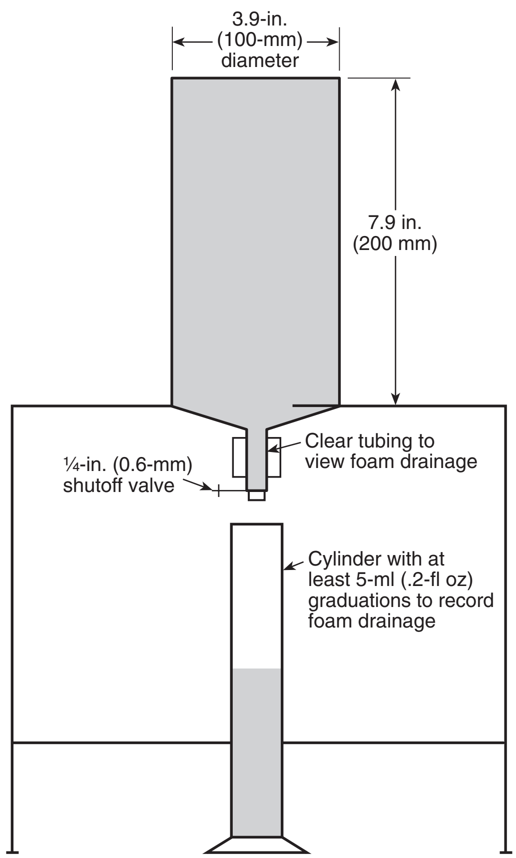


Figure C-1.1(b) 1600 ml-foam container.

C-1.3 Overhead Devices. (It is presumed that the devices are fixed and not capable of movement.) Prior to starting up the stream, the collector is situated within the discharge area where it is anticipated a representative foam pattern will occur. The two sample containers are removed prior to positioning the collector. The foam system is activated and permitted to achieve equilibrium, after which time the technician, wearing appropriate clothing, enters the area without delay. The sample containers are placed and left on the collector board until adequately filled. Stopwatches are started for each of the samples to provide the "zero" time for the drainage rate test described later. During the entry and retreat of the operator through the falling foam area, the containers should be suitably shielded from extraneous foam. Immediately after removing the samples from under the falling foam, the top should be struck off with a straight edge, and all foam wiped off from the outside of the container. The sample is then ready for analysis.

C-1.4 Pressure Foam. (It is presumed that foam is flowing under pressure from a foam pump or high-pressure aspirator toward an inaccessible tank outlet.) A 1-in. (25.4-mm) pipe tap fitted with a globe valve should be located as close to the point of foam application as practicable. The connection should terminate in an approximate 18-in. (457-mm) section of flexible rubber tubing to facilitate filling the sample container. When drawing the sample, the valve should be opened as wide as possible without causing excessive splashing and air entrainment in the container. Care should be exercised to eliminate air pockets in the sample. As each container is filled, a stopwatch is started to provide the "zero" time for the drainage test described later. Any excess foam is struck off the top with a straight edge, and all foam clinging to the outside of the container is wiped off. The sample is then ready for analysis.

C-1.5 Foam Chambers. In some instances where the foam makers are integral with the foam chambers on the top ring of a tank, the methods of sampling described in C-1.1 through C-1.4 may not be workable. In this case it will be necessary to improvise, making sure any unusual procedures or conditions are pointed out in reporting the results. Where access can be gained to a flowing foam stream, the container can be inserted into the edge of the stream to split off a portion for the sample. The other alternative is to scoop foam from a layer or blanket already on the surface. Here an attempt should be made to obtain a full cross section of foam from the entire depth but without getting any fuel below the foam layer. The greatest difficulty inherent in sampling from a foam blanket is the undesirable lag-in-time factor involved in building up a layer deep enough to scoop a sample. At normal rates of application, it may take a few minutes to build up the several inches in depth required, and this time is likely to affect the test results. The degree of error thus incurred will in turn depend on the type of foam involved, but it can vary from zero percent to several hundred percent.

In a Moeller tube installation, it is advisable to sample right alongside the tube as foam oozes out in sufficient volume.

Immediately after filling the container, a stopwatch is started to provide the "zero" time for the drainage test described later. Any excess foam is struck off the top with a straight edge and all foam wiped off from the outside of the container. The sample is then ready for analysis.

C-1.6 Foam Testing. The foam samples, as obtained in the procedures described in C-1.1 through C-1.5, are analyzed for expansion, 25 percent drainage time, and foam solution concentration. It is recommended that duplicate samples be obtained whenever possible and the results averaged for the final value. However, when a shortage of personnel or equipment or both creates a hardship, one sample should be considered acceptable.

The following apparatus is required:

(a) Two 1600-ml (54.1-fl oz) sample containers

(b) One foam collector board

(c) One balance [triple beam balance, 2610 g (5.7 lb) capacity]

C-1.7 Procedure. Prior to the testing, the empty containers fitted with a drain hose and clamp should be weighed to obtain the tare weight. (All containers should be adjusted to the same tare weight to eliminate confusion in handling.) Each foam sample is weighed to the nearest gram and the expansion calculated from the following equation:

$$\frac{1600}{(\text{full weight} - \text{empy weight})} = \text{Expansion}$$

(All weights to be expressed in grams)

C-1.8 Foam 25 Percent Drainage Time Determination. The rate at which the foam solution drops out from the foam mass is called the drainage rate and is a specific indication of degree of water retention ability and the fluidity of the foam. A single value is used to express the relative drainage rates of different foams in the "25 percent drainage time," which is the time in minutes that it takes for 25 percent of the total solution contained in the foam in the sample containers to drain.

The following apparatus is required:

(a) Two stopwatches

(b) One sample stand

(c) 100-ml (3.38 fl oz) capacity plastic graduates

C-1.9 Procedure. This test is performed on the same sample as used in the expansion determination. Dividing the net weight of the foam sample by 4 will give the 25 percent volume (in milliliters) of solution contained in the foam. To determine the time required for this volume to drain out, the sample container should be placed on a stand, as indicated in Figure C-1.1(b) and the accumulated solution in the bottom of the container should be drawn off into a graduate at regular, suitable intervals. The time intervals at which the accumulated solution is drawn off are dependent on the foam expansion. For foams of expansion 4 to 10, 30-second intervals should be used, and for foams of expansion 10 and higher, 4-minute intervals should be used because of the slower drainage rate of these foams. In this way, a time-drainage-volume relationship is obtained, and after the 25 percent volume has been exceeded, the 25 percent drainage time is interpolated from the data. The following example shows how this is done. The net weight of the foam sample is 180 grams. Since 1 gram of foam solution occupies a volume of essentially 1 ml (.68 fl oz), the total volume of foam solution contained in the given sample is 180 ml (6.1 fl oz).

$$\text{Expansion} = \frac{1600}{180 \text{ ml}} = 8.9$$

$$25\ \%\ \text{volume} = \frac{180 \text{ ml}}{4} = 45\ \text{l}$$

The time-solution volume data is recorded as shown in Table C-1.9.

The 25 percent volume of 45 ml (1.52 fl oz) falls between the 2.0- and 2.5-minute period. The proper increment to add to the lower value of 2.0 minutes is determined by interpolation of the data:

$$\frac{45 \text{ ml (25\% vol.)} - 40 \text{ ml (2.0 min vol.)}}{50 \text{ ml (2.5 min vol.)} - 40 \text{ ml (2.0 min vol.)}} = \frac{5}{10} = \frac{1}{2}$$

The 25 percent drainage time is halfway between 2.0 and 2.5 minutes, or 2.25 minutes, which is rounded off to 2.3 minutes.

An effort should be made to conduct foam tests with water temperatures between 60°F and 80°F (15.6°C and 26.7°C). The water, air, and foam temperatures should be noted in the results. Lower water temperature tends to depress the expansion values and increase the drainage time values.

NOTE: When handling fast-draining foams, remember that they lose their solution rapidly and that the expansion determination should be carried out with speed in order not to miss the 25 percent drainage volume. The stopwatch is started at the time the foam container is filled and continues to run during the time the sample is being weighed. It is recommended that expansion weighing be deferred until after the drainage curve data has been received.

Table C-1.9 Foam Sample Drain Time

Time (min)	Drained Solution Volume (ml)	Drained Solution Volume (fl oz)
0	0	0
0.5	10	.34
1.0	20	.68
1.5	30	1.0
2.0	40	1.4
2.5	50	1.7
3.0	60	2.0

C-2 Foam Solution Concentration Determination.

C-2.1 General. This test is used to determine the percent concentration of a foam concentrate in the water being used to generate foam. It typically is used as a means of determining the accuracy of a system's proportioning equipment. If the level of foam concentrate injection varies widely from that of the design, it may abnormally influence the expansion and drainage foam quality values, which may influence the foam's fire performance.

There are two acceptable methods for measuring foam concentrate percentage in water. Both methods are based on comparing foam solution test samples to premeasured solutions that are plotted on a baseline graph of percent concentration versus instrument reading.

C-2.1.1 Refractive Index Method. A handheld refractometer is used to measure the refractive index of the foam solution samples. This method is not particularly accurate for AFFF or alcohol-resistant AFFFs since they typically exhibit very low refractive index readings. For this reason, the conductivity method may be preferred where these products are used.

C-2.1.1.1 Equipment. A base (calibration) curve is prepared using the following apparatus:

(a) Four 100-ml (3.4-fl oz) or larger plastic bottles with caps

(b) One measuring pipette [10 ml (0.34 fl oz)] or syringe [10 cc (0.34 fl oz)]

(c) One 100-ml (3.4-fl oz) or larger graduated cylinder

(d) Three plastic-coated magnetic stirring bars

(e) One handheld refractometer — American Optical Model 10400 or 10441, Atago NI, or equivalent

(f) Standard graph paper

(g) Ruler or other straight edge

C-2.1.1.2 Procedure. Using water and foam concentrate from the system to be tested, make up three standard solutions using the 100-ml (3.4-fl oz) or larger graduate. These samples should include the nominal intended percentage of injection, the nominal percentage plus 1 percent, and the nominal percentage minus 1 percent. Place the water in the 100-ml (3.4-fl oz) or larger graduate (leaving adequate space for the foam concentrate), and then carefully measure the foam concentrate samples into the water using the syringe. Use care not to pick up air in the foam concentrate samples. Pour each measured foam solution from the 100-ml (3.4-fl oz) or larger graduate into a 100-ml (3.4-fl oz) plastic bottle. Each bottle should be marked with the percent solution it contains. Add a plastic stirring bar to the bottle, cap it, and shake it thoroughly to mix the foam solution.

After thoroughly mixing the foam solution samples, a refractive index reading should be taken of each percentage foam solution sample. This is done by placing a few drops of the solution on the refractometer prism, closing the cover plate, and observing the scale reading at the dark field intersection. Since the refractometer is temperature compensated, it may take 10 to 20 seconds for the sample to be read properly. It is important to take all refractometer readings at ambient temperatures of 50°F (10°C) or above.

Using standard graph paper, plot the refractive index readings on one axis and the percent concentration readings on the other. *(See Figure C-2.1.1.2.)* This plotted curve will serve as the known baseline for the test series. Set the solution samples aside in the event the measurements need to be checked.

C-2.1.1.3 Sampling and Analysis. Collect foam solution samples from the proportioning system, using care to be sure the sample is taken at an adequate distance downstream from the proportioner being tested. Take refractive index readings of the sample and compare them to the plotted curve to determine the percentage of the samples.

C-2.1.2 Conductivity Method. This method is based on changes in electrical conductivity as foam concentrate is added to water. A handheld conductivity meter *(as shown in Figure C-2.1.2)* is used to measure the conductivity of foam solutions in microsiemen units. Conductivity is a very accurate method, provided there are substantial changes in conductivity, as foam concentrate is added to the water in relatively low percentages. Since salt or brackish water is very conductive, this method may not be suitable due to small conductivity changes as foam concentrate is added. It will be necessary to make foam and water solutions in advance to determine if adequate changes in conductivity can be detected if the water source is salty or brackish.

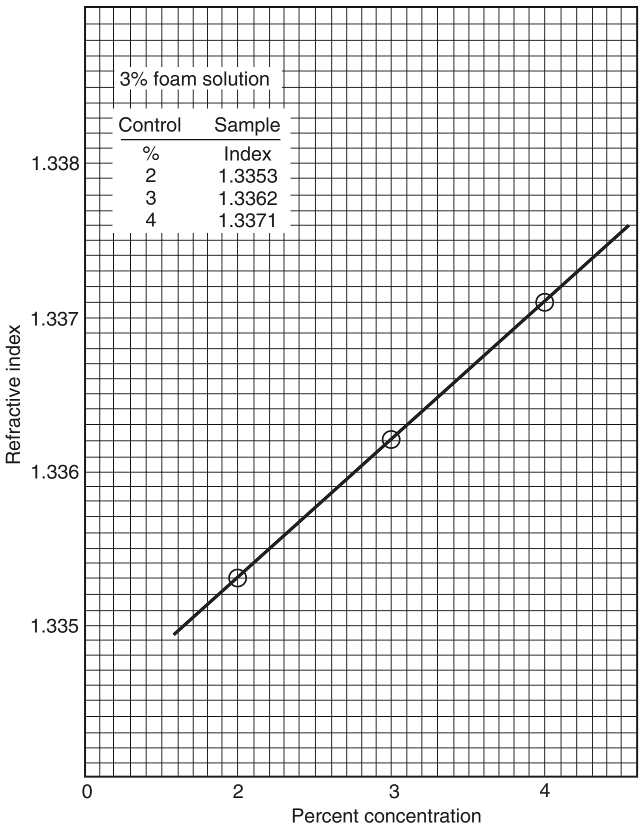


Figure C-2.1.1.2 Typical graph of refractive index versus foam concentration.

C-2.1.2.1 Equipment. Prepare a base (calibration) curve using the following apparatus:

(a) Four 100-ml (3.4-fl oz) or larger plastic bottles with caps

(b) One measuring pipette [10 ml (0.34 fl oz)] or syringe [10 cc (0.34 fl oz)]

(c) One 100-ml (3.4-fl oz) or larger graduated cylinder

(d) Three plastic-coated magnetic stirring bars

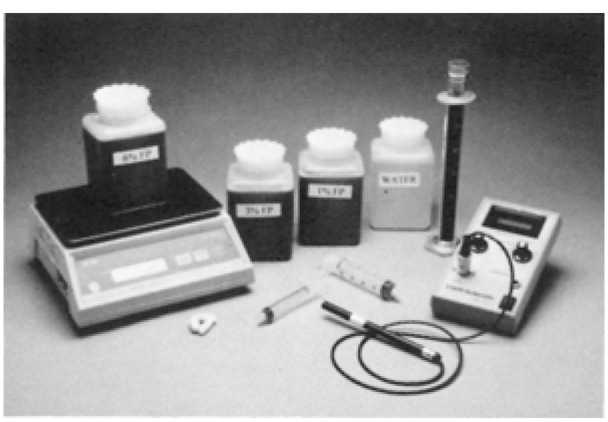


Figure C-2.1.2 Equipment needed for conductivity method of proportioning measurement.

(e) A portable temperature compensated conductivity meter — Omega Model CDH-70, VWR Scientific Model 23198-014, or equivalent

(f) Standard graph paper

(g) Ruler or other straight edge

C-2.1.2.2 Procedure. Using the water and foam concentrate from the system to be tested, make up three standard solutions using the 100-ml (3.4-fl oz) or larger graduate. These samples should include the nominal intended percentage of injection, the nominal percentage plus 1 percent, and the nominal percentage minus 1 percent. Place the water in the 100-ml (3.4-fl oz) or larger graduate (leaving adequate space for the foam concentrate), and then carefully measure the foam concentrate samples into the water using the syringe. Use care not to pick up air in the foam concentrate samples. Pour each measured foam solution from the 100-ml (3.4-fl oz) or larger graduate into a 100-ml (3.4-fl oz) or larger plastic bottle. Each bottle should be marked with the percent solution it contains. Add a plastic stirring bar to the bottle, cap it, and shake it thoroughly to mix the foam solution.

After making the three foam solutions in this manner, measure the conductivity of each solution. Refer to the instructions that came with the conductivity meter to determine proper procedures for taking readings. It will be necessary to switch the meter to the correct conductivity range setting in order to obtain a proper reading. Most synthetic-based foams used with fresh water result in foam solution conductivity readings of less than 2000 microsiemens. Protein-based foams generally produce conductivity readings in excess of 2000 in fresh water solutions. Due to the temperature compensation feature of the conductivity meter, it may take a short time to obtain a consistent reading.

Once the solution samples have been measured and recorded, set the bottles aside for control sample reference. The conductivity readings then should be plotted on the graph paper. *(See Figure C-2.1.2.2.)* It is most convenient to place the foam solution percentage on the horizontal axis and the conductivity readings on the vertical axis.

Use a ruler or straight edge to draw a line that approximates connecting all three points. While it may not be possible to hit all three points with a straight line, they should be very close. If not, repeat the conductivity measurements and, if necessary, make new control sample solutions until all three points plot in a nearly straight line. This plot will serve as the known base (calibration) curve to be used for the test series.

C-2.1.2.3 Sampling and Analysis. Collect foam solution samples from the proportioning system using care to be sure the sample is taken at an adequate distance downstream from the proportioner being tested. Using foam solution samples that are allowed to drain from expanded foam may produce misleading conductivity readings and, therefore, this procedure is not recommended.

Once one or more samples have been collected, read their conductivity and find the corresponding percentage from the base curve prepared from the control sample solutions.

C-3 Interpretation of Foam Test Results. Where the intent of conducting the tests described in C-1 and C-2 is to check the operating efficiency or standby condition, it is necessary only to compare the results with the manufacturers' standards. The manufacturers should be consulted if any appreciable deviations occur.

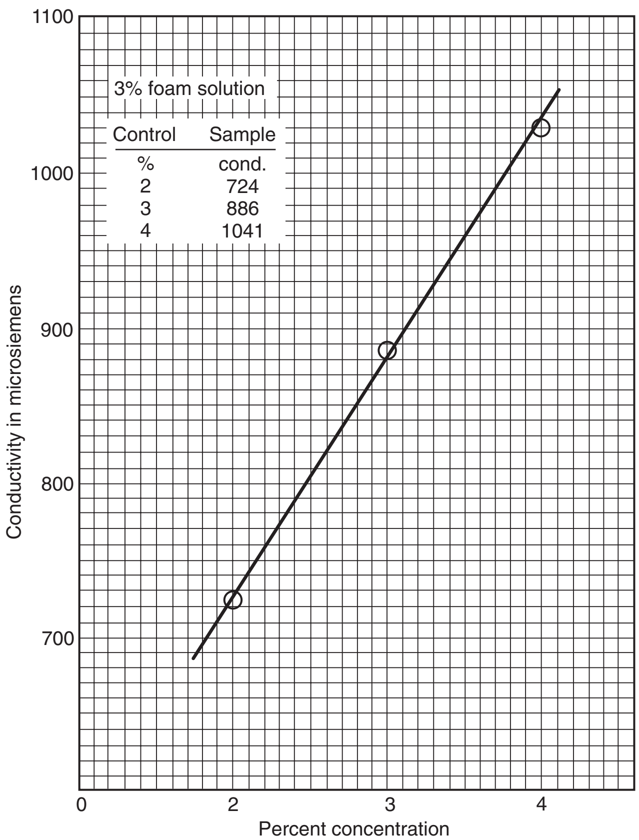


Figure C-2.1.2.2 Typical graph of conductivity versus foam concentration.

After a short period of experience with the test procedure, it will be observed that foams exist in a wide variety of physical properties. Not only may the expansion vary in value from 3 to 20, but at the same time the 25 percent drainage time may also vary from a few seconds to several hours. These variations result in foams that range in appearance from a watery consistency to the stiffest whipped cream.

It is observed here that the foam solution rapidly drains out of the very watery foams, while the drop out is very slow with the stiff foams. It is not possible to make a foam that is fluid and free flowing and, at the same time, able to hold onto its foam solution. From the standpoint of quickly forming a cohesive foam blanket and rapid flow around obstructions, a fluid-type foam is desirable; however, foams of this nature lose their water more rapidly, which may reduce their resistance to flame burnback and shorten the effective time of sealability. On the other hand, foams that retain their water for a long time are stiff and do not spread readily over a burning area. Thus, good fire-fighting practice indicates a compromise between these two opposite foam properties in order to obtain an optimum foam. An optimum foam is defined as that foam, with physical properties defined by expansion and drainage time, that will extinguish a fire faster, at a lower application rate, or with less water consumed than any other foam.

Numerous test fires conducted in the course of research and development work have shown that the characteristics of an optimum foam depend on the type of the fire and the manner of foam application. Experience over many years of satisfactory results has supported this viewpoint. For example, in a large fuel storage tank, foam may be gently applied from one chamber and be required to flow 65 ft (19.8 m) across a burning surface to seal off the fuel. In this case, the optimum foam is physically different from that applied in a splashing manner from a turret that can direct the foam application as needed, and the foam has to flow no more than 42 in. (12.7 mm) to form a seal. The formation of a complete specification for the various methods of application has not as yet been accomplished; however, for guidance purposes, the best data available to date are presented.

C-4 Inspection of Foam Concentrate. In order to determine the condition of the apparatus and foam concentrate and in order to train personnel, foam should be produced annually with portable foam nozzles. Following this operation, the concentrate container (can) should be cut open and examined for deposits of sludge, scale, and so forth, which are capable of impairing the operation of the equipment.

Where the concentrate is stored in tanks, a sample should be drawn from the bottom of the tank annually, and actual foam production tested as specified above, using a portable foam nozzle and the withdrawn sample to verify the quality of foam produced.

In the event that sludging of the concentrate is noted, the manufacturer should be promptly consulted.

Appendix D Foam Fire Fighting Data Sheet

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

D-1 The following data sheet is used to record and evaluate data on actual fires and fire tests where fire-fighting foam is used. This data may be considered in evaluating suggestions for changes to this standard. Persons having knowledge of such fires are requested to complete the form and send it to the following:

National Fire Protection Association

1 Batterymarch Park

P.O. Box 9101

Quincy, MA 02269-9101

In the case of multiple attacks or reflashes of the same fire, additional data sheets should be prepared for each attack.

Appendix E Foam Environmental Issues

E-1 Overview. Fire-fighting foams as addressed in this standard serve a vital role in fire protection throughout the world. Their use has proven to be essential for the control of flammable liquid fire threats inherent in airport operations, fuel farms and petroleum processing, highway and rail transportation, marine applications, and industrial facilities. The ability of foam to rapidly extinguish flammable liquid spill fires has undoubtedly saved lives, reduced property loss, and helped minimize the global pollution that can result from the uncontrolled burning of flammable fuels, solvents, and industrial liquids.

Foam fire fighting data sheet

Date of fire ____________________
Time of fire ____________________
Location [City, state, county, facility (if available)]
____
Size of fire (Dimension of tank, pit, spill, and extent involved) ____________________
Ignition source (Specify if test) ____________________
Method of detection ____________________
Fuel: General type (indicate percentage polar solvent content or additives) ____________________
Reid vapor pressure (psia) ____________________
Initial temperature ____________________
Boiling range ____________________
Flash point ____________________
Depth before fire: Fuel ____________________
Water bottom ____________________
Depth after fire: Fuel ____________________
Water bottom ____________________
Ambient conditions: Temperature ____________________
Humidity ____________________
Precipitation ____________________
Wind direction ____________________
Wind speed ____________________
Including gusts ____________________
Preburn time prior to foam application ____________________
____
Control time (90%) ____________________
Extinguishing time ____________________
Discharging time after extinguishment ____________________
____
Time of reflash ____________________
Foam concentrate
[Foam type (Estimate amount of each type)]
Protein (P) ____________________
Fluoroprotein (FP) ____________________
Aqueous film-forming (AFFF) ____________________
Film-forming fluoroproteins (FFP) ____________________
Synthetic (SYN) ____________________
Alcohol-resistant (ARF) ____________________
(Indicate if P, FP or AFFF base) ____________________
Other (Name) ____________________

Discharge devices
Type (Handline, monitor, foam maker, subsurface injection, etc.) ____________________
Method of application (plunging, gentle, backboard) ____________________
Number ____________________
Flow through each ____________________
Estimated pressure at each ____________________
Application rate, total (gpm/ft^2) ____________________
Proportioning
Percent (1%, 3%, 6%, other. Identify if premix) ____________________
Type of proportioner: (Pickup tube, in-line inductor, pressure proportioning tank, pump proportioner, metered proportioning, bladder tank and controller, coupled water motor pump)
____
Water
Salt ____ Fresh ____ Other (Explain) ____________________
Temperature ____________________
Source ____________________
Additives ____________________
Description of hazard/facility (Indoors, outdoors, confined or unconfined, material of tank) ____________________
____
Exterior cooling rate ____________________
Foam properties (Identify apparatus used)
Apparatus ____________________
Expansion ____________________
25% drainage ____________________
Burnback ____________________
Sealability ____________________
Brief scenario ____________________
____
Unusual circumstances ____________________
Test laboratory or other third-party observer ____________________
____
Submitter ____________________
Point of contact ____________________
Telephone number ____________________

Figure D-1 Foam fire-fighting data sheet

However, with the ever increasing environmental awareness, recent concern has focused on the potential adverse environmental impact of foam solution discharges. The primary concerns are fish toxicity, biodegradability, treatability in wastewater treatment plants, and nutrient loading. All of these are of concern when the end-use foam solutions reach natural or domestic water systems. Additionally, the U.S. Environmental Protection Agency (EPA) has highlighted a potential problem with some foam concentrates by placing glycol ethers and ethylene glycol, common solvent constituents in some foam concentrates, on the list of hazardous air pollutants under the 1990 Clean Air Act Amendments.

The purpose of this appendix is to address the following:

(a) Provide foam users with summary information on foam environmental issues

(b) Highlight applicable regulatory status

(c) Offer guidelines for coping with regulations, and provide suggested sources for additional information

(d) Encourage planning for foam discharge scenarios (including prior contact with local wastewater treatment plant operators)

It should be emphasized that it is not the intent of this appendix to limit or restrict the use of fire-fighting foams. The foam committee believes that the fire safety advantages of using foam are greater than the risks of potential environmental problems. The ultimate goal of this section is to foster use of foam in an environmentally responsible manner so as to minimize risk from their use.

E-2 Scope. The information provided in this section covers foams for Class B combustible and flammable liquid fuel fires. Foams for this purpose include protein foam, fluoroprotein foam, film-forming fluoroprotein foam (FFFP), and synthetic foams such as aqueous film-forming foam (AFFF).

Some foams contain solvent constituents that may require reporting under federal, state, or local environmental regulations. In general, synthetic foams, such as AFFF, biodegrade more slowly than protein-based foams. Protein-based foams may be more prone to nutrient loading and treatment facility "shock loading" due to their high ammonia nitrogen content and rapid biodegradation, respectively.

This section is primarily concerned with the discharge of foam solutions to wastewater treatment facilities and to the environment. The discharge of foam concentrates, while a related subject, is a much less common occurrence. All manufacturers of foam concentrate deal with clean-up and disposal of spilled concentrate in their MSDS sheets and product literature.

E-3 Discharge Scenarios. A discharge of foam water solution is most likely to be the result of one of four scenarios:

(a) Manual fire-fighting or fuel-blanketing operations

(b) Training

(c) Foam equipment system tests

(d) Fixed system releases

These four scenarios include events occurring at such places as aircraft facilities, fire fighter training facilities, and special hazards facilities (such as flammable/hazardous warehouses, bulk flammable liquid storage facilities, and hazardous waste storage facilities). Each scenario is considered separately in E-3.1 through E-3.4.

E-3.1 Fire-Fighting Operations. Fires occur in many types of locations and under many different circumstances. In some cases it is possible to collect the foam solution used; and in others, such as in marine fire fighting, it is not. These types of incidents would include aircraft rescue and fire-fighting operations, vehicular fires (i.e., cars, boats, train cars), structural fires with hazardous materials, and flammable liquid fires. Foam water solution that has been used in fire-fighting operations will probably be heavily contaminated with the fuel or fuels involved in the fire. It is also likely to have been diluted with water discharged for cooling purposes.

In some cases, the foam solution used during fire department operations can be collected. However, it is not always possible to control or contain the foam. This can be a consequence of the location of the incident or the circumstances surrounding it.

Event-initiated manual containment measures are the operations usually executed by the responding fire department to contain the flow of foam water solution when conditions and manpower permit. Those operations include the following measures:

(a) *Blocking sewer drains.* This is a common practice used to prevent contaminated foam water solution from entering the sewer system unchecked. It is then diverted to an area suitable for containment.

(b) *Portable dikes.* These are generally used for land-based operations. They can be set up by the fire department personnel during or after extinguishment to collect run-off.

(c) *Portable booms.* These are used for marine-based operations, which are set up to contain foam in a defined area. These generally involve the use of floating booms within a natural body of water.

E-3.2 Training. Training is normally conducted under circumstances conducive to the collection of spent foam. Some fire training facilities have had elaborate systems designed and constructed to collect foam solution, separate it from the fuel, treat it, and — in some cases — re-use the treated water. At a minimum, most fire training facilities collect the foam solution for discharge to a wastewater treatment facility. Training may include the use of special training foams or actual fire-fighting foams.

Training facility design should include a containment system. The wastewater treatment facility should first be notified and should give permission for the agent to be released at a prescribed rate.

E-3.3 System Tests. Testing primarily involves engineered, fixed foam fire-extinguishing systems. Two types of tests are conducted on foam systems: acceptance tests, conducted pursuant to installation of the system; and maintenance tests, usually conducted annually to ensure the operability of the system. These tests can be arranged to pose no hazard to the environment. It is possible to test some systems using water or other nonfoaming, environmentally acceptable liquids in the place of foam concentrates if the authority having jurisdiction permits such substitutions.

In the execution of both acceptance and maintenance tests, only a small amount of foam concentrate should be discharged to verify the correct concentration of foam in the foam water solution. Designated foam water test ports can be designed into the piping system so that the discharge of foam water solution can be directed to a controlled location. The controlled location can consist of a portable tank that would be transported to an approved disposal site by a licensed contractor. The remainder of the acceptance test and maintenance test should be conducted using only water.

E-3.4 Fixed System Releases. This type of release is generally uncontrolled, whether the result of a fire incident or a malfunction in the system. The foam solution discharge in this type of scenario may be dealt with by event-initiated operations or by engineered containment systems. Event-initiated operations encompass the same temporary measures that would be taken during fire department operations; portable dikes, floating booms, and so forth. Engineered containment would be based mainly on the location and type of facility, and would consist of holding tanks or areas where the contaminated foam water solution would be collected, treated, and sent to a wastewater treatment facility at a prescribed rate.

E-4 Fixed Systems. Facilities can be divided into those without an engineered containment system and those with an engineered containment system.

E-4.1 Facilities Without Engineered Containment. Given the absence of any past requirements to provide containment, many existing facilities simply allow the foam water solution to flow out of the building and evaporate into the atmosphere or percolate into the ground. The choices for containment of foam water solution at such facilities fall into two categories: event-initiated manual containment measures and installation of engineered containment systems.

Selection of the appropriate choice is dependent on the location of the facility, the risk to the environment, the risk of an automatic system discharge, the frequency of automatic system discharges, and any applicable rules or regulations.

"Event-initiated manual containment measures" will be the most likely course of action for existing facilities without engineered containment systems. This may fall under the responsibility of the responding fire department and include such measures as blocking storm sewers, constructing temporary dikes, and deploying floating booms. The degree of such measures will primarily be dictated by location as well as available resources and manpower.

The "installation of engineered containment systems" is a possible choice for existing facilities. Retrofitting an engineered containment system is costly and may adversely affect facility operations. There are special cases, however, that may warrant the design and installation of such systems. Such action is a consideration where an existing facility is immediately adjacent to a natural body of water and has a high frequency of activation.

E-4.2 Facilities with Engineered Containment. Any engineered containment system will usually incorporate an oil/water separator. During normal drainage conditions (i.e., no foam solution runoff), the separator functions to remove any fuel particles from drainage water. However, when foam water solution is flowing the oil/water separator must be bypassed so that the solution is diverted directly to storage tanks. This can be accomplished automatically by the installation of motorized valves set to open the bypass line upon activation of the fixed fire-extinguishing systems at the protected property.

The size of the containment system is dependent on the duration of the foam water flow, the flow rate, and the maximum anticipated rainfall in a 24-hour period. Most new containment systems will probably only accommodate individual buildings. However, some containment systems may be designed to accommodate multiple buildings dependent upon the topography of the land and early identification in the overall site planning process.

The specific type of containment system selected will also be dependent upon location, desired capacity, and function of facilities in question. They include earthen retention systems, belowground tanks, open-top inground tanks, and sump and pump designs (i.e., lift stations) piped to aboveground or inground tanks.

The earthen retention designs consist of open-top earthen berms, which usually rely upon gravity-fed drainage piping from the protected building. They may simply allow the foam water solution to percolate into the ground or may include an impermeable liner. Those containing an impermeable liner may be connected to a wastewater treatment facility or may be suction pumped out by a licensed contractor.

Closed-top, belowground storage tanks may be the least environmentally acceptable design approach. They usually consist of a gravity-fed piping arrangement and can be suction pumped out or piped to a wastewater treatment facility. A potential and often frequent problem associated with this design is the leakage of ground water or unknown liquids into the storage tank.

Open-top, belowground storage tanks are generally lined concrete tanks that may rely on gravity-fed drainage piping or a sump and pump arrangement. These may accommodate individual or multiple buildings. They must also accommodate the maximum anticipated rainfall in a 24-hour period. These are usually piped to a wastewater treatment facility.

Aboveground tanks incorporate a sump and pump arrangement to closed, aboveground tanks. Such designs usually incorporate the use of one or more submersible or vertical shaft, large capacity pumps. These may accommodate individual or multiple buildings.

E-4.3 New Facilities. The decision to design and install a fixed foam water solution containment system is dependent on the location of the facility, the risk to the environment, possible impairment of facility operations, the design of the fixed foam system (i.e., automatically or manually activated), the ability of the responding fire department to execute event-initiated containment measures, and any pertinent regulations.

New facilities may not warrant the expense and problems associated with containment systems. Where the location of a facility does not endanger ground water or any natural bodies of water, this may be an acceptable choice, provided the fire department has planned emergency manual containment measures.

Where conditions warrant the installation of engineered containment systems, there are a number of considerations. They include size of containment, design and type of containment system, and the capability of the containment system to handle individual or multiple buildings.

Engineered containment systems may be a recommended protective measure where foam extinguishing systems are installed in facilities that are immediately adjacent to a natural body of water. These systems may also be prudent at new facilities, where site conditions permit, to avoid impairment of facility operations.

E-5 Disposal Alternatives. The uncontrolled release of foam solutions to the environment should be avoided. Alternative disposal options are as follows:

(a) Discharge to a wastewater treatment plant with or without pretreatment
(b) Discharge to the environment after pretreatment
(c) Solar evaporation
(d) Transportation to a wastewater treatment plant or hazardous waste facility

Foam users, as part of their planning process, should make provisions to take the actions necessary to utilize whichever of these alternatives is appropriate for their situation. Section E-6 describes the actions that may be taken, depending on the disposal alternative that is chosen.

E-6 Collection and Pretreatment of Foam Solutions Prior to Disposal.

E-6.1 Collection and Containment. The essential first step in employing any of these alternatives is collection of the foam solution. As noted above, facilities that are protected by foam systems normally have systems to collect and hold fuel spills. These systems may also be used to collect and hold foam solution. Training facilities are, in general, designed so that foam solution may be collected and held. Fire fighters responding to fires that are at other locations should attempt, insofar as it is practical, to collect foam solution run-off with temporary dikes or other means.

E-6.2 Fuel Separation. Foam solution that has been discharged on a fire and subsequently collected will usually be heavily contaminated with fuel. Since most fuels present their own environmental hazards and will interfere with foam solution pretreatment, an attempt should be made to separate as much fuel as possible from the foam solution. As noted in E-4.2, the tendency of foam solutions to form emulsions with hydrocarbon fuels will interfere with the operation of conventional fuel-water separators. An alternative is to hold the collected foam solution in a pond or lagoon until the emulsion breaks and the fuel may be separated by skimming. This may take from several hours to several days. During this time, agitation should be avoided to prevent the emulsion from reforming.

E-6.3 Pretreatment Prior to Discharge.

E-6.3.1 Dilution. Foam manufacturers and foam users recommend dilution of foam solution before it enters a wastewater treatment plant. There is a range of opinion on the optimum degree of dilution. It is generally considered that the concentration of foam solution in the plant influent should not exceed 1700 ppm (588 gal of plant influent per gallon of foam solution). This degree of dilution is normally sufficient to prevent shock loading and foaming in the plant. However, each wastewater treatment plant must be considered as a special case, and those planning a discharge of foam solution to a wastewater treatment facility should discuss this subject with the operator of the facility in advance.

Diluting waste foam solution 588:1 with water is an impractical task for most facilities, especially when large quantities of foam solution are involved. The recommended procedure is to dilute the foam solution to the maximum amount practical and then meter the diluted solution into the sewer at a rate which, based on the total volume of plant influent, will produce a foam solution concentration of 1700 ppm or less.

For example, if the discharge is to be made to a 6 million gal/day treatment plant, foam solution could be discharged at the rate of 7 gpm (6,000,000 gal/day divided by 1440 minutes/day divided by 588 equals 7 gpm). The difficulties of metering such a low rate of discharge can be overcome by first diluting the foam solution by 10:1 or 20:1, permitting discharge rates of 70 or 140 gpm respectively.

Dilution should also be considered if the foam solution is to be discharged to the environment in order to minimize its impact.

E-6.3.2 Defoamers. The use of defoamers will decrease, but not eliminate, foaming of the foam solution during pumping, dilution, and treatment. The foam manufacturer should be consulted for recommendations as to the choice of effective defoamers for use with a particular foam concentrate.

E-6.3.3 Other Pretreatments. Several chemical and mechanical pretreatments — such as precipitation, coagulation, absorption on activated carbon, and ultra filtration (i.e., reverse osmosis) — have been studied experimentally. There was no known instance of these processes having been used in the field at the time of the preparation of this document. Foam users should contact the foam manufacturer for up-to-date information on this subject.

E-7 Discharge of Foam Solution to Wastewater Treatment Facilities. Biological treatment of foam solution in a wastewater treatment facility is an acceptable method of disposal. However, foam solutions have the potential to cause plant upsets and other problems if not carefully handled. The reasons for this are explained in E-7.1 through E-7.4.

E-7.1 Fuel Contamination. Foam solutions have a tendency to emulsify hydrocarbon fuels and some polar fuels that are only slightly soluble in water. Water-soluble polar fuels will mix with foam solutions. The formation of emulsions will upset the operation of fuel/water separators and potentially cause the carryover of fuel into the waste stream. Many fuels are toxic to the bacteria in wastewater treatment plants.

E-7.2 Foaming. The active ingredients in foam solutions will cause copious foaming in aeration ponds, even at very low concentrations. Aside from the nuisance value of this foaming, the foaming process tends to suspend activated sludge solids in the foam. These solids can be carried over to the outfall of the plant. Loss of activated sludge solids can also reduce the effectiveness of the wastewater treatment. This could cause water quality problems such as nutrient loading in the waterway to which the outfall is discharged. Because some surfactants in foam solutions are highly resistant to biodegradation, nuisance foaming may occur in the outfall waterway.

E-7.3 BOD (Biological Oxygen Demand). Foam solutions have high BODs compared to the normal influent of a wastewater treatment plant. If large quantities of foam solution are discharged to a wastewater treatment plant, shock loading can occur, causing a plant upset.

Before discharging foam solutions to a wastewater treatment plant, the plant operator should be contacted. This should be done as part of the emergency planning process. The plant operator will require, at a minimum, a Material Safety Data Sheet (MSDS) on the foam concentrate, an estimate of the five-day BOD content of the foam solution, an estimate of the total volume of foam solution to be discharged, the time period over which it will be discharged, and, if the foam concentrate is protein-based, an estimate of the ammonia nitrogen content of the foam solution.

The foam manufacturer will be able to provide BOD and ammonia nitrogen data for the foam concentrate, from which the values for foam solution may be calculated. The other required information is site-specific and should be developed by the operator of the facility from which the discharge will occur.

E-7.4 Treatment Facilities. Foam concentrates or solutions may have an adverse effect on microbiologically based oily water treatment facilities. The end user should take due account of this before discharging foam systems during testing or training.

E-8 Foam Product Use Reporting.

Federal (U.S.), state and local environmental jurisdictions have certain chemical reporting requirements that apply to chemical constituents within foam concentrates. In addition, there are also requirements that apply to the flammable liquids to which the foams are being applied.

For example, according to the U.S. Environmental Protection Agency (EPA), the guidelines in E-8.1 through E-8.4 must be adhered to.

E-8.1 Releases of ethylene glycol in excess of 5000 pounds are reportable under U.S. EPA Comprehensive Environmental Response Compensation & Liability Act (CERCLA) Sections 102(b) & 103(a). Ethylene glycol is generally used as a freeze-point suppressant in foam concentrates.

E-8.2 As of June 12, 1995, the EPA issued a final rule 60 *CFR* 30926 on several broad categories of chemicals, including the glycol ethers. The EPA has no reportable quantity for any of the glycol ethers. Thus foams containing glycol ethers (butyl carbitol) are not subject to EPA reporting. Consult the foam manufacturer's MSDS to determine if glycol ethers are contained in a particular foam concentrate.

E-8.3 The EPA does state that CERCLA liability continues to apply to releases of all compounds within the glycol ether category, even if reporting is not required. Parties responsible for releases of glycol ethers are liable for the costs associated with cleanup and any natural resource damages resulting from the release.

E-8.4 The end user should contact the relevant local regulating authority regarding specific current regulations.

E-9 Environmental Properties of Hydrocarbon Surfactants and Fluorochemical Surfactants.

Most fire-fighting foam agents contain surfactants. Surfactants or surface active agents are compounds which reduce the surface tension of water. They have both a strongly “water-loving” portion and a strongly “water-avoiding” portion.

Dish soaps, laundry detergents, and personal health care products — such as shampoos — are common household products that contain hydrocarbon surfactants.

Fluorochemical surfactants are similar in composition to hydrocarbon surfactants; however a portion of the hydrogen atoms have been replaced by fluorine atoms. Unlike chlorofluorocarbons (CFCs) and some other volatile fluorocarbons, fluorochemical surfactants are not ozone depleting and are not restricted by the Montreal Protocol or related regulations. Fluorochemical surfactants also have no effect on global warming or climate change. AFFF, Fluoroprotein Foam, and FFFP are foam liquid concentrates that contain fluorochemical surfactants.

There are environmental concerns with use of surfactants that should be kept in mind when using these products for extinguishing fires or for fire training. These concerns are as follows:

(a) All surfactants have a certain level of toxicity.

(b) Surfactants used in fire-fighting foams cause foaming.

(c) Surfactants used in fire-fighting foams may be persistent. (This is especially true of the fluorine functional group of fluorochemical surfactants.)

(d) Surfactants may be mobile in the environment. They may move with water in aquatic ecosystems and leach through soil in terrestial ecosystems.

E-9.1 through E-9.5 explain what each of these properties mean and what the properties mean in terms of how these compounds should be handled.

E-9.1 Toxicity of Surfactants. Fire-fighting agents, used responsibly and following Material Safety Data Sheet instructions, pose little toxicity risk to people. However, some toxicity does exist. The toxicity of the surfactants in fire-fighting foams, including the fluorochemical surfactants, is a reason to prevent unnecessary exposure to people and to the environment. It is a reason to contain and treat all fire-fighting foam wastes whenever feasible. One should always make plans to contain wastes from training exercises and to treat them following the supplier’s disposal recommendations as well as the requirements of local authorities.

Water that foams when shaken due to contamination from fire-fighting foam should not be ingested. Even when foaming is not present, it is prudent to evaluate the likelihood of drinking water supply contamination and to use alternate water sources until one is certain that surfactant concentrations of concern no longer exist. Suppliers of fire-fighting foams should be able to assist in evaluating the hazard and in recommending laboratories that can do appropriate analysis when necessary.

E-9.2 Surfactants and Foaming. Many surfactants can cause foaming at very low concentrations. This can cause aesthetic problems in rivers and streams, and both aesthetic and operational problems in sewers and wastewater treatment systems. When too much fire-fighting foam is discharged at one time to a wastewater treatment system, serious foaming can occur. The bubbles of foam that form in the treatment system can trap and bring flocks of the activated sludge that treat the water in the treatment system to the surface. If the foam blows off the surface of the treatment system, it leaves a black or brown sludge residue where the foam lands and breaks down.

If too much of the activated sludge is physically removed from the treatment system in foam, the operation of the treatment system can be impaired. Other waste passing through the system will then be incompletely treated until the activated sludge concentration again accumulates. For this reason, the rate of fire-fighting foam solution discharged to a treatment system has to be controlled. Somewhat higher discharge rates may be possible when anti-foaming or defoaming agents are used. Foam concentrate suppliers may be contacted for guidance on discharge rates and effective anti-foaming or defoaming agents.

E-9.3 Persistence of Surfactants. Surfactants may biodegrade slowly and/or only partially biodegrade. The fluorochemical surfactants are known to be very resistant to chemical and biochemical degradation. This means that, while the non-fluorochemical portion of these surfactants may break down, the fluorine containing portion may likely remain. This means that after fire-fighting foam wastes are fully treated, the waste residual could still form some foam when shaken. It could also still have some toxicity to aquatic organisms if not sufficiently diluted.

E-9.4 Mobility of Surfactants. Tests and experience have shown that some surfactants or their residues can leach through at least some soil types. The resistance of some surfactants to biodegradation makes the mobility of such surfactants a potential concern. While a readily degradable compound is likely to degrade as it leaches through soil, this won’t happen to all surfactants. Thus, if allowed to soak into the ground, surfactants that don’t become bound to soil components may eventually reach ground water or flow out of the ground into surface water. If adequate dilution has not occurred, surfactants may cause foaming or concerns about toxicity. Therefore, it is inappropriate to allow training waste to continually seep into soil, especially in areas where water resources could be contaminated.

E-9.5 Fluorochemical Surfactants and Living Systems. Fluorochemical surfactants or their persistent degradation products are likely to be anionoic, or negatively charged compounds. As such, they could form strong ion pairs with positively charged molecules. Since positively charged molecules are frequently found in living organisms, this could be a mechanism of affinity for living systems. The release of fluorochemical surfactants back into nonliving portions of the environment could be slow because these ionic associations could be strong.

Appendix F Test Method for Marine Fire-Fighting Foam Concentrates Protecting Hydrocarbon Hazards

F-1 Introduction. The following test method has been specifically developed for use in demanding marine applications. It is derived from Federal Specification O-F-555C, which is no longer in print. It specifically incorporates a large surface area of 100 ft^2 (9.29 m^2), sealability testing, and a burnback test conducted 15 minutes after fire extinction. The test method given here incorporates a high freeboard that is subject to high temperatures; both conditions add to the difficulty of this test method. This test method uses gasoline, a highly challenging test fuel, and requires that fresh fuel be used for each test. This test utilizes a square pan. The geometry of the pan's corners better simulates the complex steel shapes found in ship's cargo holds and bilges than round fire test pans used in other test methods. The test method employs a fixed nozzle, thus removing any bias caused by an operator applying foam at the test facility.

F-2 Test Facility. The test should be conducted at a test facility acceptable to the authority having jurisdiction.

F-3 Test Apparatus.

F-3.1 Pan. The test pan should be of 10-gauge steel minimum construction measuring 10 ft (3 m) long × 10 ft (3 m) wide × 3 ft (.9 m) deep. The sides of the pan should be properly reinforced to prevent warpage due to heat generated during the test.

F-3.2 Nozzle. The test nozzle should be as shown in Figure F-3.2. Alternate nozzles should be approved by the authority having jurisdiction. The nozzle should flow 6.0 gpm (22.7 L/min) at 100-psi (689.5-kPa) inlet pressure.

F-3.3 Fuel. A minimum of 75 gal (284 L) of gasoline shall be floated on a sufficient quantity of potable water so that the fuel surface is 2 ft (.6 m) below the top edge of the tank. For each succeeding test the pan should be completely emptied of the fuel and foam residue from the previous test. The gasoline should be commercial unleaded regular motor fuel with an octane rating between 82 and 93 per Federal Specification VV-G-1690. The fuel temperature should be not less than 70°F (21°C). An alternate test fuel may be used provided that it has properties equivalent to the unleaded fuel specified above and has been approved by the authority having jurisdiction.

F-3.4 Synthetic Sea Water. The composition should be as described in ASTM D 1141, *Standard Specifications for Substitute Ocean Water.*

F-3.5 Conversion Factors.

$1\ L/min{\cdot}m^2 = 0.0147\ gpm/ft^2$

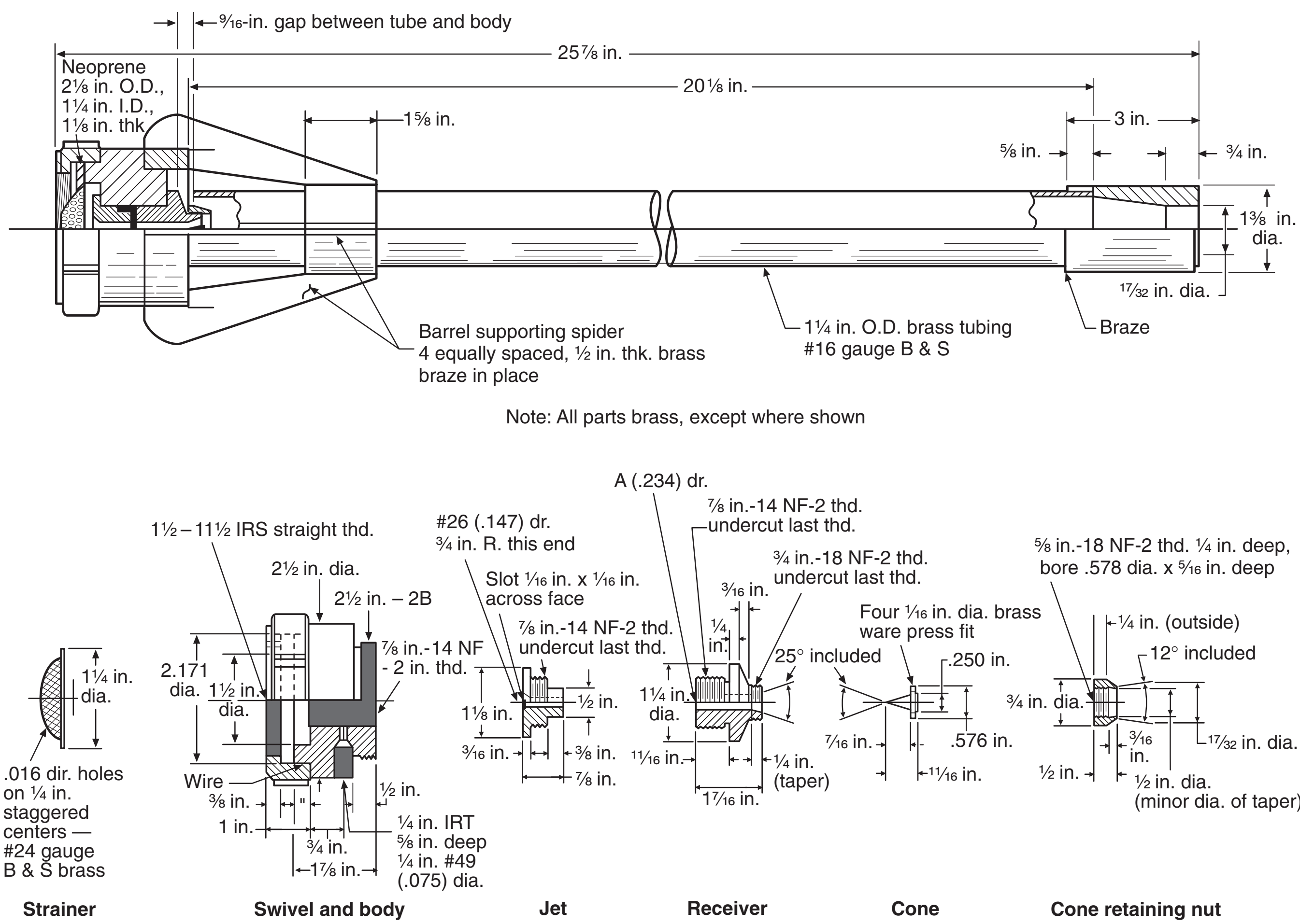
$6\ L/min{\cdot}m^2 = 0.147\ gpm/ft^2$

$3\ L/min{\cdot}m^2 = 0.0735\ gpm/ft^2$

$1\ gpm/ft^2 = 6.5\ L/min{\cdot}m^2$

$0.24\ gpm/ft^2 = 9.78\ L/min{\cdot}m^2$

F-4 Test Procedure.



For SI units: 1 in. = 25.4 mm

Figure F-3.2 Test nozzle.

F-4.1 Fire Extinguishment. Foam concentrate should be subjected to four consecutive fire tests by discharging through a 6-gpm (22.7-L/min) nozzle at an inlet gauge pressure maintained at 100 psi (689.5 kPa) ± 2 psi (13.8 kPa), and a water temperature of 68 ± 8°F (20 ± 5°C). The concentrate should be at approximately the same temperature as the water. Two of the tests should be conducted with fresh water, and two of the tests should be conducted with salt water (described above). The foam liquid solution should be premixed and applied at a rate of 3.0 percent by volume for 3 percent foams, 6.0 percent for 6 percent foams, and so forth. The nozzle should be positioned in the middle of one side of the test pan with the nozzle tip 16 in. (406.4 mm) directly above the top edge of the test pan. The fire should be permitted to burn freely for 60 seconds before foam application. The foam should be directed across the fire to strike the approximate center of the back side of the pan, 12 in. (304.8 mm) above the fuel level and should be applied for a 5-minute period. (If prior to the test, foam is discharged into the pan to align the nozzle for proper foam stream impact position on the back side of the pan, such foam should be removed from the pan prior to the test.)

(a) *Observations:*

1. Record the period required, after start of foam application, for the foam to spread over the fuel surface as "coverage" time.
2. Record the period for the fire to be extinguished except for licks of flame at the edges of the foam blanket as "control" time.
3. Record the period for complete extinguishment as "extinguishment" time.

(b) *Record:* Record the name of the manufacturer, foam type, trade name, batch number, and date of manufacture.

F-4.2 Sealability. A lighted torch should be passed continuously over the foam blanket starting 10 minutes after the end of foam discharge. Fourteen minutes after completion of foam application, the lighted torch should be applied over the foam blanket for 1 minute with the torch touching the foam blanket but not penetrating the foam blanket by more than $^1/_2$ in. (12.7 mm). The torch should touch the blanket at least every 2 ft (.6 m) along the sides of the test pan, at points where the foam blanket appears significantly less than the average thickness, in all four corners of the pan and at random points in the main area of the pan. However, the torch should not be dragged through the foam.

F-4.3 Burnback. One of the methods described in F-4.3.1 and F-4.3.2 should be used.

F-4.3.1 Method 1. Fifteen minutes after completion of the foam application, an opening 6 in.^{2} (3870 mm^2) should be made in the foam blanket approximately 2 ft (.6 m) from the side of the pan. The exposed fuel should be reignited with a torch and permitted to burn for 5 minutes. After the 5-minute burning period, the area involved in flames should be determined.

F-4.3.2 Method 2. As an alternative to Method 1, two 1-ft (.3-m) diameter stove pipes should be placed in the foam blanket during the sealability test, at least 2 ft (.6 m) from the sides of the pan, and the foam inside the stove pipes should be removed. At 15 minutes after the end of the foam discharge, the exposed fuel inside the stove pipes should be ignited by torch and permitted to burn for 1 minute. The first stove pipe should then be removed. After an additional 4-minute burning period, the area involved in flames should be determined. If, upon removal of the pipe, foam covers the exposed fuel area and extinguishes the fire, the fuel inside the second stove pipe should be ignited and allowed to burn freely for 1 minute. The second stove pipe should then be removed and the area involved at 20 minutes after the end of foam discharge should be determined. If, upon removal of the second pipe, the foam again covers the exposed fuel and extinguishes the fire, no further burnback tests are necessary.

F-5 Acceptance Criteria.

F-5.1 Fire Performance. The foam as received should have a coverage time of not more than 2 minutes, a control time of not more than 5 minutes, and complete fire extinguishment in not more than 5 minutes after start of foam application.

F-5.2 Sealability. The foam blanket should protect the fuel below the foam from reignition by a lighted torch for a period of not less than 15 minutes after the end of foam application. Any ignition of fuel vapors above the foam blanket should result in complete self-extinguishment prior to the end of the test period. Record in detail the type, location, and duration of any burning observed.

F-5.3 Burnback.

F-5.3.1 Method 1. The foam blanket should prevent the spread of fire beyond an area approximately 20 in.^{2}(12,902 mm^2).

F-5.3.2 Method 2. The area involved in flames should not exceed 2.7 ft^2 (.25 m^2).

F-6 Foam Quality. Foam quality tests should be conducted using the same batch of premix as used during the fire tests. Foam expansion and 25 percent drainage tests should be performed as explained in Appendix C.

F-7 Procedures in Case of Failure. Four consecutive successful tests are recommended. Failure of any one test will result in another series of four consecutive tests being performed successfully.

Appendix G Referenced Publications

G-1 The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 9. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

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

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems,* 1994 edition.

NFPA 11C, *Standard for Mobile Foam Apparatus,* 1995 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1996 edition.

NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems,* 1995 edition.

NFPA 16A, *Standard for the Installation of Closed-Head Foam-Water Sprinkler Systems,* 1994 edition.

NFPA 18, *Standard on Wetting Agents,* 1995 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 1996 edition.

NFPA 70, *National Electrical Code®,* 1996 edition.

NFPA 72, *National Fire Alarm Code®,* 1996 edition.

NFPA 298, *Standard on Fire Fighting Foam Chemicals for Class A Fuels in Rural, Suburban, and Vegetated Areas,* 1994 edition.

NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles,* 1995 edition.

G-1.2 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 1141, *Standard Specifications for Substitute Ocean Water,* 1990.

IEEE/ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System,* 1997.

G-1.3 Other Publications.

IBC Code *Regulation 11.3.13,* 1994.

Federal Specification O-F-555C, *Foam Liquid, Fire Extinguishing Mechanical,* 1990.

IEEE 45, *Recommended Practice for Electrical Installations on Shipboard.*

ISO 9001, *Quality Systems — Model for Quality Assurance in Design, Development, Production, Installation, and Servicing,* 1994.

ISO 9002, *Quality Systems — Model for QualityAssurance in Production, Installation, and Servicing,* 1994.

NVIC 11-82, *Deck Foam Systems for Polar Solvents.*

UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates,* March 1989.

SOLAS Regulation 61 Chapter 212.

TP 127, Canadian Standard. Ottawa, Ontario.

Material Safety Data Sheet.

Title 60 *Code of Federal Regulations,* Part 30926.

U.S. EPA Comprehensive Environmental Response Compensation & Liability Act (CERCLA) Sections 102(b) and 103(a).

United Nations Environment Programme Montreal Protocol on Substances that Deplete the Ozone Layer— Final Act 1987, UNEP/RONA, Room DCZ-0803, United Nations, New York, NY 10017.

Federal Specification VV-G-1690.

Index

-A-

-B-

-C-

-D-

-E-

-F-

-H-

-I-

-J-

-L-

-M-

-N-

-O-

-P-