

NFPA®

11

Standard for Low-, Medium-, and High-Expansion Foam

2016



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NFPA® 11

Standard for

Low-, Medium-, and High-Expansion Foam

2016 Edition

This edition of NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, was prepared by the Technical Committee on Foam and acted on by NFPA at its June Association Technical Meeting held June 22–25, 2015, in Chicago, IL. It was issued by the Standards Council on August 18, 2015, with an effective date of September 7, 2015, and supersedes all previous editions.

This document has been amended by one or more Tentative Interim Amendments (TIAs) and/or Errata. See “Codes & Standards” at www.nfpa.org for more information.

This edition of NFPA 11 was approved as an American National Standard on September 7, 2015.

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 was 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.

The 2002 edition was revised to address mixing of foam concentrates and to clarify requirements related to foam concentrate pumps. Requirements for medium- and high-expansion foam systems were included.

The 2005 edition was reorganized to provide the requirements for low-, medium-, and high-expansion foam, to better incorporate the requirements of NFPA 11A.

The 2010 edition added a new chapter to address compressed air foam systems. Unenforceable terms were removed to comply with the *Manual of Style for NFPA Technical Committee Documents*.

For the 2016 edition, the committee addressed several areas of concern. The piping requirements have been reorganized and clarified, issues regarding acceptance criteria for annual foam concentrate testing have been addressed, environmentally friendly methods of testing foam proportioners are recognized, and seal-only protection is permitted for composite roofs that meet specific criteria.

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

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



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

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Information on referenced publications can be found in Chapter 2 and Annex H.

Chapter 1 Administration

1.1* Scope.

1.1.1 This standard covers the design, installation, operation, testing, and maintenance of low-, medium-, and high-expansion and compressed air foam systems for fire protection.

1.1.2 It is not the intent of this standard to specify where foam protection is required.

1.2 Purpose.

1.2.1 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 low-, medium-, and high-expansion and com-

pressed air foam fire-extinguishing systems for interior or exterior hazards.

1.2.2 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.

1.2.3 Low-, medium-, and high- expansion foam and compressed air foam systems are intended to provide property protection and not life safety.

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

- (1) Chemical foams and systems (considered obsolete)
- (2) Deluge foam-water sprinkler or spray systems (See NFPA 16.)
- (3) Foam-water closed-head sprinkler systems (See NFPA 16.)
- (4) Combined agent systems
- (5) Mobile foam apparatus (See NFPA 1901.)
- (6) Class A foam and systems (See NFPA 1150.)

1.4 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.4.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.4.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.4.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.5 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.5.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.5.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.6 Units and Formulas. 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 1.6.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

Table 1.6 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·m ²	1 gpm/ft ² = 40.746 L/min·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 = 10 ⁵ Pa
kilopascal	kPa	1 psi = 6.895 kPa

Note: For additional conversions and information, see IEEE/ASTM SI 10.

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

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

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 2012 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2015 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2016 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 2016 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2015 edition.

NFPA 70®, *National Electrical Code*®, 2014 edition.

NFPA 72®, *National Fire Alarm and Signaling Code*, 2016 edition.

NFPA 220, *Standard on Types of Building Construction*, 2015 edition.

NFPA 1150, *Standard on Foam Chemicals for Fires in Class A Fuels*, 2010 edition.

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

NFPA 1961, *Standard on Fire Hose*, 2013 edition.

2.3 Other Publications.

2.3.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd St., 4th Floor, New York, NY 10036.

ANSI B1.20.1, *Standard for Pipe Threads, General Purpose*, 1983 (R2006).

ANSI B16.1, *Gray Iron Pipe Flanges and Flanged Fittings*, 2010.

ANSI B16.3, *Malleable Iron Threaded Fittings: Classes 150 and 300*, 2011.

ANSI B16.4, *Gray Iron Threaded Fittings, Classes 150 and 300*, 2006.

ANSI B16.5, *Pipe Flanges and Flanged Fittings: NPS 1/2 through 24 Metric/Inch Standard*, 2013.

ANSI B16.9, *Factory-Made Wrought Butt Welding Fittings*, 2012.

ANSI B16.11, *Forged Fittings, Socket-Welding and Threaded*, 2011.

ANSI B16.15, *Cast Bronze Threaded Fittings*, 1985 (R1994).

ANSI B16.24, *Cast Copper Alloy Pipe Flanges and Flanged Fittings*, 1991 (R1998).

ANSI B16.25, *Butt Welding Ends*, 2012.

2.3.2 API Publications. American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005-4070.

API 607, *Fire Test for Quarter-turn Valves and Valves Equipped with Nonmetallic Seats*, 6th edition, 2010.

API 650, *Welded Tanks for Oil Storage*, 12th edition, 2013.

2.3.3 ASME Publications. American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

ASME *Boiler and Pressure Vessel Code*, 2013.

ASME B31.1, *Power Piping Code*, 2012.

2.3.4 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM A 53, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, 2012.

ASTM A 105, *Standard Specification for Carbon Steel Forgings for Piping Applications*, 2012.

ASTM A 106, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*, 2011.

ASTM A 135, *Standard Specification for Electric Resistance-Welded Steel Pipe*, 2009.

ASTM A 182, *Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*, 2012.

ASTM A 216, *Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service*, 2012.

ASTM A 234, *Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High-Temperature Service*, 2011.

ASTM A 312, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*, 2012.

ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*, 1999.

ASTM A 795, *Standard Specification for Black and Hot-Dipped, Zinc-Coated, (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use*, 2008.

ASTM B 43, *Standard Specification for Seamless Red Brass Pipe, Standard Sizes*, 2009.

ASTM B 315, *Standard Specification for Seamless Copper Alloy Pipe and Tube*, 2012.

ASTM C 582, *Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment*, 2009.

ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)*, 2008.

ASTM D 1331, *Standard Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents*, 2011.

ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2013.

IEEE/ASTM SI 10, *American National Standard for Metric Practice*, 2010.

2.3.5 AWS Publications. American Welding Society, 550 NW LeJeune Road, Miami, FL 33126.



AWS B2.1, *Specification for Welding Procedure and Performance Qualification*, 2009.

2.3.6 IEEE Publications. IEEE, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

IEEE 45, *Recommended Practice for Electric Installations on Shipboard*, 2002.

2.3.7 IMO Publications. International Maritime Organization, 4 Albert Embankment, London SE1 7SR.

Safety of Life at Sea, SOLAS Regulations II-2/4.3 and 4.3.5.

2.3.8 ISO Publications. International Organization for Standardization, 1, ch. de la Voie-Creuse, CP 56 – CH-1211 Geneva 20 Switzerland.

ISO 7-1, *Pipe Threads Where Pressure-Tight Joints Are Made on the Threads — Part 1: Dimensions, Tolerances and Designation*, 1994.

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

UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates*, 1999.

2.3.10 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2013 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2015 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

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

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of

production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

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

3.2.7 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase “standards development process” or “standards development activities,” the term “standards” includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Combustible Liquid. Any liquid that has a closed-cup flash point at or above 37.8°C (100°F), as determined by the test procedures and apparatus set forth in Section 4.4 of NFPA 30. [30, 2015]

3.3.1.1 Class II Liquid. A liquid that has a closed-cup flash point at or above 37.8°C (100°F) and below 60°C (140°F). [30, 2015]

3.3.1.2 Class IIIA Liquid. Any Liquid that has a closed-cup flash point at or above 60°C (140°F), but below 93°C (200°F). [30, 2015]

3.3.1.3 Class IIIB Liquid. Any liquid that has a closed-cup flash point at or above 93°C (200°F). [30, 2015]

3.3.2* Concentration. The percent of foam concentrate contained in a foam solution.

3.3.3* Discharge Devices. Devices designed to discharge water or foam-water solution in a predetermined, fixed, or adjustable pattern.

3.3.3.1 Air-Aspirating Discharge Devices. Devices specially designed to aspirate and mix air into the foam solution to generate foam, followed by foam discharge in a specific design pattern.

3.3.3.2 Compressed Air Foam Discharge Devices. Devices specifically designed to discharge compressed air foam in a predetermined pattern.

3.3.3.3* Non-Air-Aspirating Discharge Devices. Devices designed to provide a specific water discharge pattern.

3.3.4 Discharge Outlet.

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

3.3.4.2* 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.

3.3.4.3 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.

3.3.5* 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.

3.3.5.1* In-Line Eductor. A Venturi-type proportioning device that meters foam concentrate at a fixed or variable concentration into the water stream at a point between the water source and a nozzle or other discharge device.

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

3.3.7 Film Formation. A property of aqueous film-forming foams and film-forming fluoroproteins characterized by a positive (>0.0 dynes/cm) spreading coefficient when measured according to ASTM D 1331 using cyclohexane as the hydrocarbon substrate and distilled water to make the foam solution.

3.3.8 Fire.

3.3.8.1 Class A Fire. A fire in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics. [10, 2013]

3.3.8.2 Class B Fire. A fire in flammable liquids, combustible liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases.

3.3.9 Flammable (Class I) Liquid. Any liquid that has a closed-cup flash point that is below 37.8°C (100°F), as determined by the test procedures and apparatus set forth in Section 4.4 of NFPA 30, and a Reid vapor pressure that does not exceed an absolute pressure of 276 kPa (40 psi) at 37.8°C (100°F), as determined by ASTM D 323, *Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)*. [30, 2015]

3.3.9.1 Class IA Liquid. Any liquid that has a closed-cup flash point below 22.8°C (73°F) and a boiling point below 37.8°C (100°F). [30, 2015]

3.3.9.2 Class IB Liquid. Any liquid that has a closed-cup flash point below 22.8°C (73°F) and a boiling point at or above 37.8°C (100°F). [30, 2015]

3.3.9.3 Class IC Liquid. Any liquid that has a closed-cup flash point at or above 22.8°C (73°F) but below 37.8°C (100°F). [30, 2015]

3.3.10* Foam. A stable aggregation of bubbles of lower density than oil or water.

3.3.10.1 Compressed Air Foam (CAF). A homogenous foam produced by the combination of water, foam concentrate, and air or nitrogen under pressure.

3.3.11 Foam Chamber. See 3.3.4.1, Fixed Foam Discharge Outlet.

3.3.12* Foam Concentrate. A concentrated liquid foaming agent as received from the manufacturer.

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

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

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

3.3.12.4 Film-Forming Foam. A concentrate that when mixed at its nominal use concentration will form an aqueous film on hydrocarbon fuels.

3.3.12.5* Fluoroprotein Foam Concentrate. A concentrate very similar to protein-foam concentrate but with a synthetic fluorinated surfactant additive.

3.3.12.6* Medium- and High-Expansion Foam Concentrate. A concentrate, usually derived from hydrocarbon surfactants, used in specially designed equipment to produce foams having foam-to-solution volume ratios of 20:1 to approximately 1000:1.

3.3.12.7* Protein Foam Concentrate. Concentrate consisting 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.

3.3.12.8 Synthetic Foam Concentrate. Concentrate based on foaming agents other than hydrolyzed proteins and including aqueous film-forming foam (AFFF) concentrates, medium- and high-expansion foam concentrates, and other synthetic foam concentrates.

3.3.12.8.1* Other Synthetic Foam Concentrate. A concentrate based on hydrocarbon surface active agents and listed as a wetting agent, foaming agent, or both.

3.3.13 Foam Concentrate Type. A classification of a foam concentrate that includes the chemical composition as defined under foam concentrate (see 3.3.12), including the use percentage, the minimum usable temperature, and the fuels on which the concentrate is effective.

3.3.14 Foam Generators.

3.3.14.1 Foam Generators — Aspirator Type. Foam generators, fixed or portable, in which jet streams of foam solution aspirate sufficient amounts of air that is then entrained on the screens to produce foam, and which usually produce foam with expansion ratios of not more than 250:1.

3.3.14.2* Foam Generators — Blower Type. Foam generators, fixed or portable, in which the foam solution is discharged as a spray onto screens through which an air-stream developed by a fan or blower is passing.

3.3.15 Foam Injection.

3.3.15.1 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.

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

3.3.16* Foam Solution. A homogeneous mixture of water and foam concentrate in the correct proportions.



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

3.3.17 Foam System Types.

3.3.17.1* Compressed Air Foam System (CAFS). A system employing compressed air foam discharge devices or hoses attached to a piping system through which foam is transported from a mixing chamber.

3.3.17.2 Fixed System. A complete installation in which foam is piped from a central foam station, discharging through fixed delivery outlets to the hazard to be protected with permanently installed pumps where required.

3.3.17.3* Mobile System. Any type of foam-producing unit that is mounted on wheels and that is self-propelled or towed by a vehicle and can be connected to a water supply or can utilize a premixed foam solution.

3.3.17.4 Portable System. Foam-producing equipment, materials, hose, and so forth that are transported by hand.

3.3.17.5* Semifixed System. A system in which the hazard is equipped with fixed discharge outlets connected to piping that terminates at a safe distance.

3.3.18* Foam-Generating Methods. Methods of generation of air foam including hose stream, foam nozzle, and medium- and high-expansion generators, foam maker, pressure foam maker (high back pressure or forcing type), or foam monitor stream.

3.3.18.1* Compressed Air Foam-Generating Method. A method of generating compressed air foam recognized in this standard by using a mixing chamber to combine air or nitrogen under pressure, water, and foam concentrate in the correct proportions.

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

3.3.20 Inductor See 3.3.5.

3.3.21 Monitor.

3.3.21.1* 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.

3.3.21.2 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.

3.3.22 Nozzle.

3.3.22.1* Foam Nozzle or Fixed Foam Maker. A specially designed hoseline nozzle or fixed foam maker designed to aspirate air that is connected to a supply of foam solution.

3.3.22.2* Self-Educting Nozzle. A device that incorporates a venturi to draw foam concentrate through a short length of pipe and/or flexible tubing connected to the foam supply.

3.3.23* 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.

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

3.3.24.1* Balanced Pressure Pump-Type Proportioning. A foam proportioning system that utilizes a foam pump and valve(s) to balance foam and water pressures at a modified venturi-type proportioner located in the foam solution delivery piping; a foam concentrate metering orifice is fitted in the foam inlet section of the proportioner.

3.3.24.1.1* In-Line Balanced Pressure Proportioning. A foam proportioning system utilizing a foam concentrate pump or a bladder tank in conjunction with a listed pressure reducing valve. At all design flow rates, the constant foam concentrate pressure is greater than the maximum water pressure at the inlet to the in-line balanced pressure proportioner. A pressure balancing valve integral to the in-line balanced pressure proportioner regulates the foam concentrate pressure to be balanced to incoming water pressure.

3.3.24.2* Coupled Water-Motor Driven Pump Proportioning. A correctly designed positive displacement water motor in the water supply line coupled to a positive displacement foam concentrate pump to provide proportioning.

3.3.24.3* Direct Injection Variable Pump Output Proportioning. A direct injection proportioning system that utilizes flowmeters for foam concentrate and water in conjunction with a variable output foam pump control system.

3.3.25 Proportioning Methods for Foam Systems. The methods of proportioning used to create the correct solution of water and foam liquid concentrate.

3.3.26* Pump Proportioner (Around-the-Pump Proportioner). A system that uses a venturi eductor installed in a bypass line between the discharge and suction side of a water pump and suitable variable or fixed orifices to induct foam concentrate from a tank or container into the pump suction line.

3.3.27 Stream.

3.3.27.1 Foam Hose Stream. A foam stream from a handline.

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

3.3.28* Spreading Coefficient. The measurement of a foam solution's potential to spread spontaneously across a hydrocarbon surface.

3.3.29 Tank.

3.3.29.1 Balanced Pressure Bladder Tank. A foam concentrate tank fitted with an internal bladder that uses waterflow through a modified venturi-type proportioner to control the foam concentrate injection rate by displacing the foam concentrate within the bladder with water outside the bladder.

3.3.29.2* Pressure Proportioning Tank. A foam concentrate tank with no bladder that uses waterflow through an orifice to displace a foam concentrate, having a specific gravity of at least 1.15, in the tank with water to add foam concentrate through an orifice into a water line at a specified rate.

Chapter 4 System Components and System Types

4.1* General. This chapter shall provide requirements for the correct use of foam system components.

4.1.1* All components shall be listed for their intended use.

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

4.2 Water Supplies.

4.2.1 Water Supplies, Including Premixed Solution.

4.2.1.1 Quality.

4.2.1.1.1* The water supply to foam systems shall be permitted to be hard or soft, fresh or salt, but shall be of a quality such that adverse effects on foam formation or foam stability do not occur.

4.2.1.1.2 No corrosion inhibitors, emulsion breaking chemicals, or any other additives shall be present without prior consultation with the foam concentrate supplier.

4.2.1.2* Quantity. The water supply shall be of a quantity to supply all the devices that shall be permitted to be used simultaneously for the specified time.

4.2.1.2.1 This quantity shall include not only the volume required for the foam apparatus but also water that shall be permitted to be used in other fire-fighting operations, in addition to the normal plant requirements.

4.2.1.2.2 Premixed solution-type systems shall not be required to be provided with a continuous water supply.

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

4.2.1.4* Temperature. Optimum foam production shall be obtained by using water at temperatures between 4°C (40°F) and 37.8°C (100°F).

4.2.1.5 Design. The water supply system shall be designed and installed in accordance with NFPA 24.

4.2.1.5.1 Strainers shall be provided where solids of a size large enough to obstruct openings or damage equipment are present.

4.2.1.5.2 Hydrants furnishing the water supply for foam equipment shall be provided in the required number.

4.2.1.5.3 Hydrants shall be located as required by the authority having jurisdiction (AHJ).

4.2.1.6 Storage. Water supply or premixed solution shall be protected against freezing in climates where freezing temperatures are expected.

4.2.2 Water and Foam Concentrate Pumps.

4.2.2.1 When water or foam concentrate pumps are required for automatic foam system operation, they shall be designed and installed in accordance with NFPA 20.

4.2.2.2 Controllers in accordance with NFPA 20 shall not be required for manual systems.

4.3 Foam Concentrates.

4.3.1 Types of Foam Concentrate.

4.3.1.1 Foam concentrate shall be listed.

4.3.1.2* The concentrate used in a foam system shall be listed for use on the specific flammable or combustible liquid to be protected.

4.3.1.3 The limitations of the listing and the manufacturers' specifications shall be followed.

4.3.1.4 Acceptable ranges for the following physiochemical properties of the foam concentrate shall be published as part of the listing to determine compliance with 12.6.2:

- (1) Density or specific gravity
- (2) pH
- (3) Refractive index
- (4)*Viscosity

4.3.1.5 Foam concentrates for protection of hydrocarbon fuels shall be one of the following types:

- (1) Protein
- (2) Fluoroprotein
- (3) Aqueous film-forming foam (AFFF)
- (4) Film-forming fluoroprotein (FFFP)
- (5) Alcohol-resistant
- (6) High-expansion
- (7) Medium-expansion
- (8) Others listed for this purpose

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

4.3.2 Concentrate Storage.

4.3.2.1 Storage Facilities.

4.3.2.1.1 Foam concentrates and equipment shall be stored in a location not exposed to the hazard they protect.

4.3.2.1.2 If housed, foam concentrates and equipment shall be in a noncombustible structure.

4.3.2.1.3 For outdoor nonautomatic systems, the AHJ shall be permitted to approve the storage of foam concentrate in a location off premises where these supplies are available at all times.

4.3.2.1.4 Loading and transportation facilities for foam concentrates shall be provided.

4.3.2.1.5 Off-premises supplies shall be of the type required for use in the systems of the given installation.

4.3.2.1.6 At the time of a fire, these off-premises supplies shall be accumulated in the required quantities, before the equipment is placed in operation, to ensure uninterrupted foam production at the design rate for the required period of time.

4.3.2.2* Quantity. The amount of concentrate shall meet the discharge requirements for the largest single hazard protected or group of hazards that are to be protected simultaneously.

4.3.2.3 Foam Concentrate Storage Tanks.

4.3.2.3.1 Bulk liquid storage tanks shall be fabricated from or be lined with materials compatible with the concentrate.

4.3.2.3.2 The storage tank shall be designed to minimize evaporation of foam concentrate.

4.3.2.3.3* Proportioning systems shall have signage to provide instruction on the proper sequence of system shutdown to prevent accidental loss of foam concentrate and/or system damage.

4.3.2.3.4 In atmospheric storage tanks, the suction inlet shall be located a minimum of 25.4 mm (1 in.) above the bottom of the tank.

4.3.2.3.5 Foam concentrate below the level of the suction inlet shall not be considered usable.

4.3.2.4 Storage Conditions.

4.3.2.4.1* 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.

4.3.2.4.2* Foam concentrates shall be stored within the listed temperature limitations.

4.3.2.4.3 Markings shall be provided on storage vessels to identify the type of concentrate and its intended concentration in solution.

4.3.2.5 Foam Concentrate Supply.

4.3.2.5.1 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 AHJ).

4.3.2.5.2 Reserve Supply of Foam Concentrate.

4.3.2.5.2.1 There shall be a reserve supply of foam concentrate to meet design requirements in order to put the system back into service after operation.

4.3.2.5.2.2 The reserve supply shall be in separate tanks or compartments, in drums or cans on the premises, or shall be able to be obtained from an approved outside source within 24 hours.

4.3.2.6 Auxiliary Supplies. Other equipment necessary to re-commission the system, such as bottles of nitrogen or carbon dioxide for premixed systems, also shall be able to be secured.

4.4 Concentrate Compatibility.

4.4.1 Compatibility of Foam Concentrates.

4.4.1.1* Different types of foam concentrates shall not be mixed for storage.

4.4.1.2 Different brands of the same type of concentrate shall not be mixed unless data are provided by the manufacturer and accepted by the AHJ to prove that they are compatible.

4.4.1.3 Low-expansion foams generated separately from protein, fluoroprotein, FFFP, AFFP, and alcohol-resistant concentrates shall be permitted to be applied to a fire in sequence or simultaneously.

4.4.2* Foam Compatibility with Dry Chemical Agents.

4.4.2.1 The manufacturers of the dry chemical and foam concentrate to be used in the system shall confirm that their products are mutually compatible.

4.4.2.2 Where used, limitations imposed on either of the agents alone shall be applied.

4.5 Foam Proportioning. The method of foam proportioning shall conform to one of the following:

- (1) Self-educing nozzle
- (2) In-line eductor
- (3) Pressure proportioners (with or without bladder)
- (4) Around-the-pump proportioners
- (5) Direct injection variable output foam pump system
- (6) Coupled water-motor driven pump proportioner
- (7) Balanced pressure pump-type proportioners

4.5.1* The proportioning system shall meet the listed minimum flow rate based on the minimum and maximum system discharge flow rate.

4.6* Foam Concentrate Pumps.

4.6.1 The design and materials of construction for foam concentrate pumps shall be in accordance with NFPA 20.

4.6.2 Special attention shall be paid to the type of seal or packing used. Seals or packing used shall be compatible with the foam concentrate.

4.6.3 A foam concentrate pump shall have the capacity to meet the maximum system demand.

4.6.4 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 under any condition at the point of concentration injection.

4.7 Piping.

4.7.1* Foam Concentrate Pipe Materials.

4.7.1.1* Foam concentrate pipe and valves shall be made of one of the following materials:

- (1) Brass (red or naval)
- (2) Bronze
- (3) Stainless steel (304 or 316)
- (4) Other material, in accordance with the foam concentrate manufacturer's certification of compatibility with the foam concentrate and as approved by the AHJ

4.7.1.2* Carbon steel pipe shall not be used.

4.7.1.3 Pipe carrying foam concentrate shall not be galvanized.

4.7.1.4 Foam concentrate pipe shall conform to one of the following standards:

- (1) ASTM A312
- (2) ASTM B43
- (3) ASTM B315
- (4) Other standards as allowed by 4.7.1.1 (4), 4.7.1.2, and 4.7.1.3

4.7.1.5 In piping with dissimilar metals, dielectric components shall be used to insulate and reduce the possibility of galvanic corrosion.

4.7.1.6 Selection of pipe wall thickness shall conform to one of the following:

- (1) Schedule 40
- (2) ASME B31.1

4.7.1.7* For the purpose of computing friction loss in the foam concentrate piping, the following shall be used:

- (1) Darcy-Weisbach formula for (Newtonian) foam concentrates
- (2) Manufacturers' friction loss data for alcohol-resistant (non-Newtonian) foam concentrates

4.7.1.8 Flushing and drainage valves/connections for dry foam concentrate piping shall be installed in the standby condition.

4.7.1.9 Dry foam concentrate piping shall be pitched a minimum of 4 mm/m (½ in. over 10 ft) to allow for drainage.

4.7.2* Foam Solution Pipe Materials.

4.7.2.1* Foam solution pipe shall be made of one of the following materials:

- (1) Galvanized steel
- (2) Stainless steel

- (3) Internal/external corrosion-resistant pipe in accordance with the foam manufacturer's specification for compatibility and acceptable to the authority having jurisdiction
- (4) Unprotected carbon steel pipe, when the discharge devices are closed to the atmosphere

4.7.2.2 Where exposed to corrosive influences, the piping shall be corrosion resistant or protected against corrosion.

4.7.2.3 Pipe within the hazard area shall be rated for the pressure and temperature involved.

4.7.2.4 Pipe within the hazard area shall be able to withstand the anticipated exposure to fire.

4.7.2.5 Nonmetallic foam solution piping shall be listed for the intended application.

4.7.2.6 Metallic foam solution pipe shall not be less than standard weight.

4.7.2.7 Foam solution pipe shall conform to one of the following standards:

- (1) ASTM A53
- (2) ASTM A135
- (3) ASTM A795
- (4) Other standards as allowed in 4.7.2.1(3)

4.7.2.8 Underground foam solution pipe shall be in accordance with NFPA 24.

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

- (1) Galvanized steel pipe — 120
- (2) Other C-values for corrosion-resistant piping materials in accordance with NFPA 13

4.7.2.10 Foam solution distribution piping shall be pitched a minimum of 4 mm/m (½ in. over 10 ft) to allow for drainage.

4.7.3 Fittings.

4.7.3.1* Foam Concentrate Fittings.

4.7.3.1.1 Foam concentrate piping shall use fittings made of the following materials, as appropriate to the foam concentrate pipe material:

- (1) Brass (red or naval)
- (2) Bronze
- (3) Stainless steel (304 or 316)
- (4) Other material, in accordance with the foam concentrate manufacturer's certification of compatibility, with approval from the AHJ, and as permitted by 4.7.3.1.2

4.7.3.1.2 Foam concentrate fittings shall not be carbon steel or galvanized.

4.7.3.1.3 Foam concentrate fittings shall not be less than standard class weight.

4.7.3.1.4 Foam concentrate fitting shall be in accordance with one of the following or as permitted by the AHJ:

- (1) ANSI B16.5
- (2) ANSI B16.11
- (3) ANSI B16.15
- (4) ANSI B16.24

4.7.3.2 Foam Solution Fittings.

4.7.3.2.1 Foam solution fittings shall be one of the following:

- (1) Galvanized steel
- (2) Stainless steel

- (3) Other material, in accordance with the manufacturer's certification of compatibility and with approval of the AHJ
- (4) Unprotected carbon steel pipe, when discharge devices are closed to the atmosphere
- (5) Internally/externally coated materials that are listed for the application

4.7.3.2.2 Foam solution fittings shall not be less than standard class weight.

4.7.3.2.3 Foam solution fittings shall be in accordance with one of the following or as permitted by the AHJ:

- (1) ANSI B16.1
- (2) ANSI B16.3
- (3) ANSI B16.4
- (4) ANSI B16.5
- (5) ANSI B16.9
- (6) ANSI B16.11
- (7) ANSI B16.25
- (8) ASTM A 234

4.7.3.2.4 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.

4.7.3.2.5 Listed rubber or other elastomeric-gasketed fittings shall be permitted to be used in fire-exposed areas if the foam system is actuated automatically.

4.7.3.2.6 Listed rubber or other elastomeric-gasketed fittings shall be permitted to be used in fire-exposed areas if the foam system is actuated manually and high-temperature-rated extra-heavy-duty grooved fittings and gaskets have been tested in accordance with API 607 and meet these criteria within industry standards.

4.7.4 Joining of Pipes and Fittings.

4.7.4.1 Threaded Pipe.

4.7.4.1.1 Pipe threading shall be in conformance with ANSI B1.20.1 or ISO 7-1.

4.7.4.1.2 PTFE tape or the foam concentrate manufacturer's compatible thread-locking compounds shall be used at pipe joints in the foam concentrate supply line.

4.7.4.2 Grooved Pipe. Dimensions of cut- and roll-grooves and outside diameters of piping materials shall conform to the manufacturers' recommendations and the listing laboratories' certifications.

4.7.4.3* Welded Pipe.

4.7.4.3.1 Field welding shall conform to the requirements of AWS B2.1 or equivalent.

4.7.4.3.2 Shop welding shall conform to the requirements of Section 6.5 in NFPA 13.

4.7.4.3.3 Precautions shall be taken to ensure that the openings are fully cut out and that no obstructions remain in the waterway.

4.7.4.3.4 Precautions shall be taken to ensure that no galvanic corrosion occurs between piping and fittings.

4.7.5 Strainers.

4.7.5.1 Strainers shall be provided where solids of a size large enough to obstruct openings or damage equipment are present.

4.7.5.2 The ratio of the strainer's open basket area to its inlet pipe area shall be at least 10:1.

4.7.5.2.1 The net open area of the strainer shall be at least four times the area of the suction piping.

4.7.5.2.2 Strainer mesh size shall be in accordance with the pump manufacturer's recommendations.

4.7.6* Valves.

4.7.6.1 All valves for water and foam solution lines shall be of the indicator type, such as OS&Y or post indicator.

4.7.6.2 Automatic valves for foam concentrate lines shall be listed for this service.

4.7.6.3 Valve specifications for water use shall be permitted outside the hazard or diked area.

4.7.6.4 Inside the hazard or diked area, automatic control valves and shutoff valves shall be of steel or other alloy capable of withstanding exposure to fire temperatures.

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

- (1) Electrical, in accordance with *NFPA 72*
- (2) Locked
- (3) Sealed

4.8 System Types. The following four types of systems shall be permitted:

- (1) Fixed
- (2) Semifixed
- (3) Mobile
- (4) Portable

4.9 Operation and Control of Systems.

4.9.1 Methods of Actuation.

4.9.1.1 Systems shall be permitted to be actuated automatically or manually.

4.9.1.2 All systems shall have provisions for manual actuation.

4.9.2 Automatically Actuated Systems.

4.9.2.1 An automatic system shall be activated by automatic detection equipment.

4.9.2.2 Operation shall be controlled by listed or approved mechanical, electrical, hydraulic, or pneumatic means.

4.9.2.3 Where operation is automatic, a reliable source of energy shall be used.

4.9.2.4 The need for an alternate power supply shall be determined by the AHJ.

4.9.2.5* Automatic Detection Equipment.

4.9.2.5.1 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.

4.9.2.5.2 Where approved by the AHJ, small systems for localized hazards shall be permitted to be unsupervised.

4.9.2.6* Electric automatic detection equipment and any auxiliary electric equipment, if in hazardous areas, shall be designed expressly for use in such areas.

4.9.2.7 The system shall be permitted to be arranged to shut off automatically after a predetermined operating time.

4.9.2.7.1 Automatic shutdown and the predetermined operating time shall be approved by the AHJ.

4.9.2.7.2 Where automatic shutdown is required, an alarm condition shall remain until manually reset.

4.9.2.8 Detection System.

4.9.2.8.1 The detection system shall activate a local alarm as well as an alarm at a constantly attended location.

4.9.2.8.2 The detection system's alarms also shall be actuated when the system is operated manually.

4.9.3 Manually Actuated Systems.

4.9.3.1 Controls for manually actuated systems shall be located in a place removed from the hazard zone to permit them to be operated in an emergency, yet close enough to ensure operator knowledge of fire conditions.

4.9.3.2 The location and purposes of the controls shall be indicated and shall be related to the operating instructions.

4.9.4 Equipment.

4.9.4.1 All operating devices shall be designed for the service conditions they encounter.

4.9.4.2 Operating devices shall not be rendered inoperative, or be susceptible to inadvertent operation, by environmental factors such as high or low temperature, atmospheric humidity or pollution, or marine conditions.

4.9.4.3 Operating device systems shall have means for manual actuation.

Chapter 5 Low-Expansion System Design

5.1* Types of Hazards. This chapter shall cover design information for the use of low-expansion foam to protect outdoor storage tanks, interior flammable liquid hazards, loading racks, diked areas, and nondiked spill areas.

5.2 Outdoor Fixed Roof (Cone) Tanks. The following methods for protecting exterior fixed-roof tanks shall be included within this section and shall not be considered to be in any order of preference:

- (1) Foam monitors and handlines
- (2) Surface application with fixed foam discharge outlets
- (3) Subsurface application
- (4) Semisubsurface injection methods

5.2.1 Supplementary Protection. In addition to the primary means of protection, supplementary protection shall be provided in accordance with the requirements found in Section 5.9.

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

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

5.2.4 Design Criteria for Foam Monitors and Handlines.

5.2.4.1 Limitations.

5.2.4.1.1 Monitor nozzles shall not be used as the primary means of protection for fixed-roof tanks over 18 m (60 ft) in diameter.

5.2.4.1.2 Foam handlines shall not be permitted to be used as the primary means of protection for fixed-roof tanks over 9 m (30 ft) in diameter or those over 6 m (20 ft) in height.

5.2.4.2 Foam Application Rates.

5.2.4.2.1* To determine actual solution flow requirements, consideration shall be given to potential foam losses from wind, and other factors shall be included in the calculations.

5.2.4.2.2* The design parameters for the use of monitors and handline nozzles to protect tanks containing hydrocarbons shall be in accordance with Table 5.2.4.2.2.

5.2.4.3* Tanks Containing Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams.

5.2.4.3.1* Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to regular (nonalcohol-resistant) foams shall use alcohol-resistant foams.

5.2.4.3.2* For liquids of a depth greater than 25.4 mm (1 in.), monitor and foam hose streams shall be limited for use with special alcohol-resistant foams listed and/or approved for the purpose.

5.2.4.3.3 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.

5.2.4.4 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 shall be permitted.

5.2.5 Design Criteria for Surface Application with Fixed Foam Discharge Outlets.

5.2.5.1* Fixed Foam Discharge Outlets.

5.2.5.1.1 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.

5.2.5.1.2 Where two or more discharge outlets are required, the outlets shall be spaced equally around the tank periphery.

5.2.5.1.2.1 Such outlets shall be individually piped and separately valved for isolation outside the dike area in accordance with 9.5.1.

5.2.5.1.2.2 Each outlet shall be sized to deliver foam at the minimum application rate or higher.

5.2.5.1.3 Fixed foam discharge outlets shall be attached 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.

5.2.5.1.4 Fixed foam discharge outlets shall be attached so that displacement of the roof will not subject them to damage.

5.2.5.1.5 Fixed foam discharge outlets shall be provided with seal, frangible under low pressure, to prevent entrance of vapors into foam outlets and pipelines.

5.2.5.1.6 Fixed foam discharge outlets shall be provided with inspection means to allow maintenance and for inspection and replacement of vapor seals.

5.2.5.2 Design Criteria for Tanks Containing Hydrocarbons.

5.2.5.2.1* Fixed-roof (cone) tanks shall be provided with approved fixed foam discharge outlets as indicated in Table 5.2.5.2.1.

Table 5.2.4.2.2 Foam Handline and Monitor Protection for Fixed-Roof Storage Tanks Containing Hydrocarbons

Hydrocarbon Type	Minimum Application Rate		Minimum Discharge Time (minutes)
	L/min · m ²	gpm/ft ²	
Flash point between 37.8°C and 60°C (100°F and 140°F)	6.5	0.16	50
Flash point below 37.8°C (100°F) or liquids heated above their flash points	6.5	0.16	65
Crude petroleum	6.5	0.16	65

Notes:

(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 5.2.4.3. 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.

(2) Flammable liquids having a boiling point of less than 37.8°C (100°F) 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 8.1 L/min · m² (0.2 gpm/ft²) or more.

(3) Care should be taken in applying portable foam streams to high-viscosity materials heated above 93.3°C (200°F). 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.



Table 5.2.5.2.1 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
m	ft	
Up to 24	Up to 80	1
Over 24 to 36	Over 80 to 120	2
Over 36 to 42	Over 120 to 140	3
Over 42 to 48	Over 140 to 160	4
Over 48 to 54	Over 160 to 180	5
Over 54 to 60	Over 180 to 200	6
Over 60	Over 200	6
		Plus 1 outlet for each additional 465 m ² (5000 ft ²)

5.2.5.2.2* Minimum Discharge Times and Application Rates. Where 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 5.2.5.2.2.

5.2.5.2.3 If the apparatus available has a delivery rate higher than 4.1 L/min·m² (0.1 gpm/ft²), a proportionate reduction in the time figure shall be permitted to be made, provided that the time is not less than 70 percent of the minimum discharge times shown.

Table 5.2.5.2.2 Minimum Discharge Times and Application Rates for Type II Fixed Foam Discharge Outlets on Fixed-Roof (Cone) Storage Tanks Containing Hydrocarbons

Hydrocarbon Type	Minimum Application Rate		Minimum Discharge Time (minutes)
	L/min · m ²	gpm/ft ²	
Flash point between 37.8°C and 60°C (100°F and 140°F)	4.1	0.10	30
Flash point below 37.8°C (100°F) or liquids heated above their flash points	4.1	0.10	55
Crude petroleum	4.1	0.10	55

Notes:

(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 5.2.5.3. Certain nonalcohol-resistant foams might be suitable for use with fuels containing oxygenated additives of more than 10 percent by volume. Consult manufacturer for specific listings or approvals.

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

(3) For high-viscosity liquids heated above 93.3°C (200°F), 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.

(4) Type I discharge outlets are considered obsolete, and those currently installed become Type II outlets if damaged. Refer to A.5.2.5.2.2 for additional information and minimum discharge times for existing Type I outlets.

5.2.5.3* Design Criteria for Tanks Containing Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams.

5.2.5.3.1 Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to nonalcohol-resistant foams shall require the use of alcohol-resistant foams.

5.2.5.3.2* 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.

5.2.5.3.3 Fixed-roof (cone) tanks shall be provided with approved fixed foam discharge outlets as indicated in Table 5.2.5.2.1.

5.2.5.3.4 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 5.2.5.3.4.

5.2.6 Design Criteria for Subsurface Application.

5.2.6.1* Subsurface foam injection systems shall be permitted for protection of liquid hydrocarbons in vertical fixed-roof atmospheric storage tanks.

5.2.6.1.1 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.

5.2.6.1.2 Foam concentrates and equipment for subsurface injection shall be listed for this purpose.

5.2.6.1.3 Fluoroprotein foam, AFFF, and FFFP for subsurface injection shall have expansion ratios between 2:1 and 4:1.

Table 5.2.5.3.4 Minimum Application Rates 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 (minutes) Type II Foam Discharge Outlet
Consult manufacturer for listings on specific products	55

Notes:

(1) 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.

(2) Type I discharge outlets are considered obsolete, and those currently installed become Type II outlets if damaged. Refer to A.5.2.5.2.2 for additional information and minimum discharge times for existing Type I outlets.

5.2.6.2* Foam Discharge Outlets.

5.2.6.2.1 The discharge outlet into the tank shall be permitted to be the open end of a foam delivery line or product line.

5.2.6.2.2 Outlets shall be sized so that foam generator discharge pressure and foam velocity limitations are not exceeded.

5.2.6.2.3 The foam velocity at the point of discharge into the tank contents shall not exceed 3 m/sec (10 ft/sec) for Class IB liquids or 6 m/sec (20 ft/sec) for other classes of liquids unless actual tests prove that higher velocities are satisfactory.

5.2.6.2.4 Where two or more outlets are required, they shall be located so that the foam travel on the surface cannot exceed 30 m (100 ft).

5.2.6.2.5 Each outlet shall be sized to deliver foam at the minimum application rate or higher.

5.2.6.2.6 For even foam distribution, outlets shall be permitted to be shell connections or shall be permitted to be fed through a pipe manifold within the tank from a single shell connection.

5.2.6.2.7 Rather than installing additional tank nozzles, shell connections shall be permitted to be made in manway covers.

5.2.6.2.8 Tanks shall be provided with subsurface foam discharge outlets as shown in Table 5.2.6.2.8.

5.2.6.3* Foam Discharge Outlet Elevation.

5.2.6.3.1* Foam discharge outlets shall be located so as not to discharge into a water bottom.

5.2.6.3.2 The requirement of 5.2.6.3.1 shall be accomplished by having the outlets located at least 0.3 m (1 ft) above the highest water level to prevent destruction of the foam.

5.2.6.4* 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.

5.2.6.5 Minimum Discharge Times and Application Rates.

5.2.6.5.1 The minimum discharge times and application rates for subsurface application on fixed-roof storage tanks shall be in accordance with Table 5.2.6.5.1.

Table 5.2.6.2.8 Minimum Number of Subsurface Foam Discharge Outlets for Fixed-Roof Tanks Containing Hydrocarbons

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

Notes:

(1) For Class IA liquids, see 5.2.6.1.1.

(2) Table 5.2.6.2.8 is based on extrapolation of fire test data on 7.5 m (25 ft), 27.9 m (93 ft), and 34.5 m (115 ft) diameter tanks containing gasoline, crude oil, and hexane, respectively.

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

(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 5.2.6.5.1 Minimum Discharge Times and Application Rates for Subsurface Application on Fixed-Roof Storage Tanks

Hydrocarbon Type	Minimum Application Rate		Minimum Discharge Time (minutes)
	L/min · m ²	gpm/ft ²	
Flash point between 37.8°C and 60°C (100°F and 140°F)	4.1	0.1	30
Flash point below 37.8°C (100°F) or liquids heated above their flash points	4.1	0.1	55
Crude petroleum	4.1	0.1	55

Notes:

(1) The maximum application rate shall be 8.1 L/min · m² (0.20 gpm/ft²).

(2) For high-viscosity liquids heated above 93.3°C (200°F), 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.

5.2.6.5.2* In cases where liquid hydrocarbons contain foam-destructive products, the manufacturer of the foam concentrate shall be consulted for recommendations based on listings and/or approvals.

5.2.6.5.3 If the apparatus available has a delivery rate higher than 4.1 L/min · m² (0.1 gpm/ft²), a proportionate reduction in the time figure shall be permitted to be made, provided that the time is not less than 70 percent of the minimum discharge time shown and that the maximum foam velocity is in accordance with 5.2.6.2.3.

5.2.7* Semisubsurface Systems. All equipment used in semisubsurface systems shall be listed or approved for this purpose.

5.3* Outdoor Open-Top Floating Roof Tanks. Outdoor open-top floating roof tanks shall be as illustrated in Figure 5.3(a) through Figure 5.3(d).

5.3.1 Tanks equipped with the following floating roof types shall not be covered in Section 5.3:

- (1) Roofs made from floating diaphragms
- (2) Roofs made from plastic blankets
- (3) Roofs made from plastic or other flotation material, even if encapsulated in metal or fiberglass
- (4) Roofs that rely on flotation device closures that are easily submerged if damaged
- (5) Pan roofs

5.3.2 Systems for tanks so equipped shall be designed in accordance with 5.4.2.2.

5.3.3* Types of Fires Anticipated.

5.3.3.1 Subsurface and Semisubsurface Injection. 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.

5.3.3.2 Seal Area Protection. The foam protection facilities for an open-top floating roof tank seal area shall be based on 5.3.2 through 5.3.5.

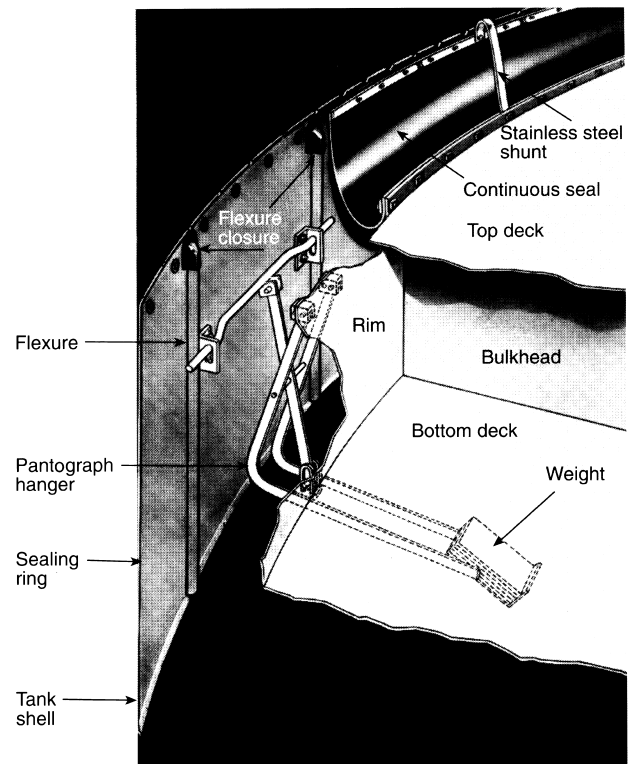
5.3.4 Methods of Seal Fire Protection.

5.3.4.1 The following methods for fire protection of seals in open-top floating roof tanks shall be as required in 5.3.5 through 5.3.7:

- (1) Fixed discharge outlets
- (2) Foam handlines
- (3) Foam monitors

5.3.4.2 Supplementary Protection. In addition to the primary means of protection, supplementary protection shall be provided in accordance with the requirements of Section 5.9.

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

**FIGURE 5.3(a) Pantograph-Type Seal Open-Top Floating Roof Tank.**

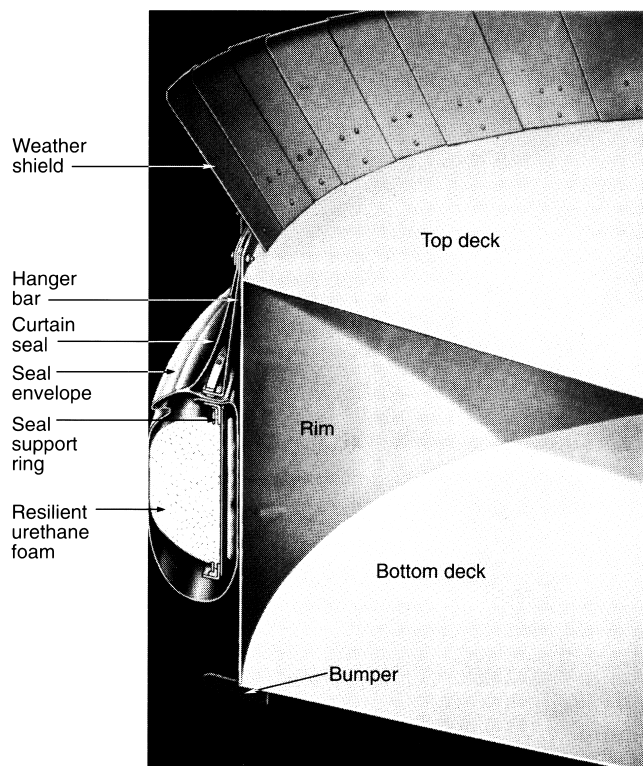


FIGURE 5.3(b) Tube Seal Open-Top Floating Roof Tank.

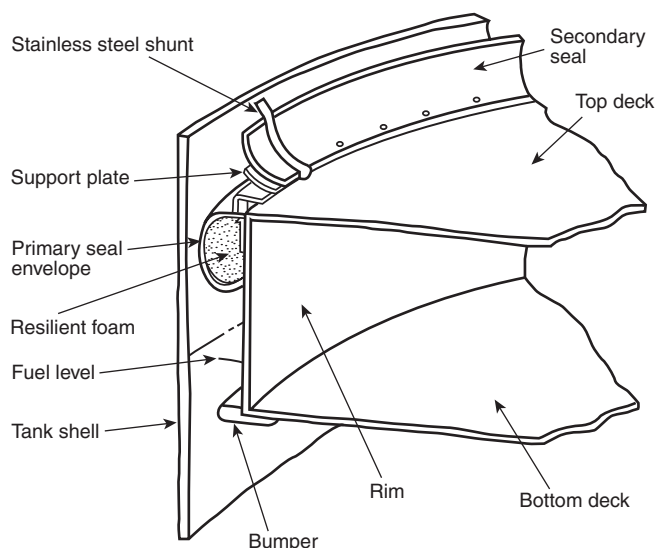


FIGURE 5.3(c) Double Seal System for Floating Roofs.

5.3.5 Fixed Discharge Outlets Design Criteria for Seal Area Protection.

5.3.5.1 Application of foam from fixed discharge outlets shall be permitted to be achieved by either of the following two methods:

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

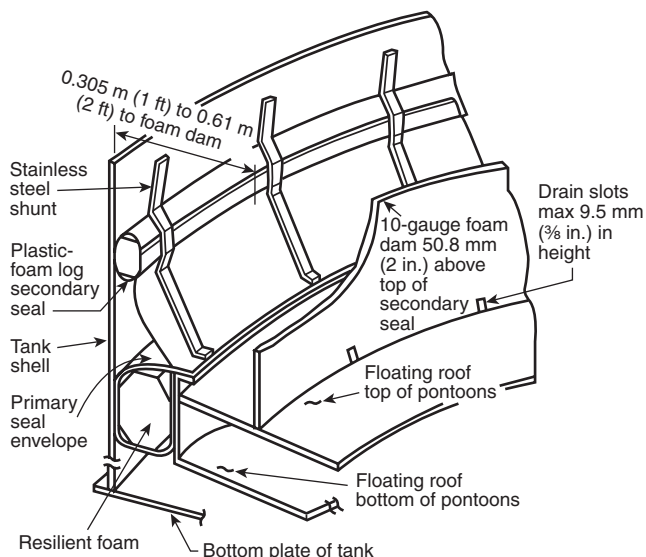


FIGURE 5.3(d) Double Seal System for Floating Roofs Using Plastic-Foam Log (Secondary Seal).

- (2) 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.

5.3.5.2* Top-of-Seal Method with Foam Dam.

5.3.5.2.1 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.

5.3.5.2.2 The following shall be permitted to be two methods of application of fixed foam discharge outlets:

- (1) Fixed foam discharge outlets (normally Type II) mounted above the top of the tank shell
- (2) Fixed foam discharge outlets mounted on the periphery of the floating roof

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

5.3.5.3 Top-of-Seal System Design.

5.3.5.3.1 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 5.3.5.3.1 and Figure 5.3.5.3.1.

5.3.5.3.2 The requirements specified in Table 5.3.5.3.1 apply to tanks containing hydrocarbons or flammable and combustible materials requiring alcohol-resistant foams.

5.3.5.3.3 The required minimum application rates specified in Table 5.3.5.3.1 shall apply, unless listings for specific products require higher application rates where Type II fixed foam discharge outlets are used.

5.3.5.3.4 If the application rate is higher than the minimum rate specified in Table 5.3.5.3.1, the discharge time shall be permitted to be reduced proportionately, provided that the reduced time is not less than 70 percent of the minimum discharge times specified.

Table 5.3.5.3.1 Top-of-Seal Fixed Foam Discharge Protection for Open-Top and Internal Floating Roof Tanks

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

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.

5.3.5.3.5 Below Primary Seal or Weather Shield Method.

5.3.5.3.5.1 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 5.3.5.3.5.1.

5.3.5.3.5.2 A foam dam shall be installed if a tube seal is used and the top of the tube seal is less than 152 mm (6 in.) below the top of the pontoon.

5.3.5.3.6 Below-the-Seal or Weather Shield System.

5.3.5.3.6.1 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 5.3.5.3.6.1.

5.3.5.3.6.2 The requirements shown in Table 5.3.5.3.6.1 shall apply to tanks containing hydrocarbons or flammable and combustible materials requiring alcohol-resistant foams.

5.3.5.3.6.3 The required minimum application rates shown in Table 5.3.5.3.6.1 shall apply unless listings for specific products require higher application rates when Type II fixed foam discharge outlets are used.

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

5.3.5.4 Foam Dam Design Criteria.

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

5.3.5.4.2 The foam dam shall be welded or otherwise fastened to the floating roof.

5.3.5.4.3 The foam dam shall be designed to retain foam at the seal area, at a depth to cover the seal area while causing the foam to flow laterally to the point of seal rupture.

5.3.5.4.3.1 Dam height shall be at least 305 mm (12 in.).

5.3.5.4.3.2 The dam shall extend at least 51 mm (2 in.) above a metal secondary seal or a combustible secondary seal using a plastic-foam log.

5.3.5.4.3.3 Dam height shall be at least 51 mm (2 in.) higher than any burnout panels in metal secondary seals.

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

5.3.5.4.5* To allow drainage of rainwater, the foam dam bottom shall be slotted on the basis of 278 mm² of slot area per m² of dammed area (0.04 in.² of slot area per ft² of dammed area), restricting drain slots to a maximum 9.5 mm (⅜ in.) in height as shown in Figure 5.3.5.4.5.

5.3.6* Foam Handline Design Criteria for Seal Area Protection.

5.3.6.1 Foam handlines shall be permitted to be used from the windgirder for extinguishment of seal fires in open-top floating roof tanks.

5.3.6.2 Listed or approved equipment shall be used.

5.3.7 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.

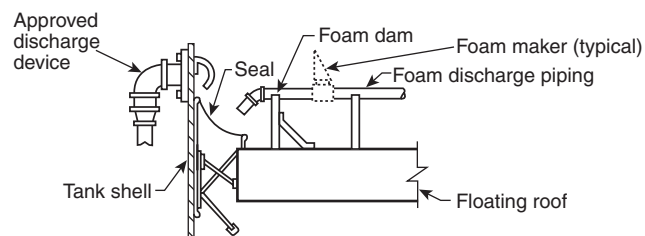
5.4* Outdoor Covered (Internal) Floating Roof Tanks. See Figure 5.4.

5.4.1 Requirements for tanks equipped with the following floating roof types shall not be covered in Section 5.4:

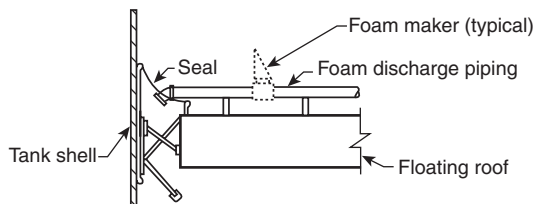
- (1) Roofs made from floating diaphragms
- (2) Roofs made from plastic blankets
- (3) Roofs made with plastic or other flotation material, even if encapsulated in metal or fiberglass, except as permitted in 5.4.2
- (4) Roofs that rely on flotation device closures that are easily submerged if damaged
- (5) Pan roofs

5.4.2 Seal area protection systems shall be permitted for the following types of roof construction:

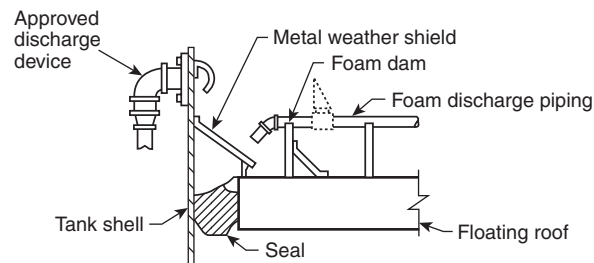
- (1) Steel double deck
- (2) Steel pontoon



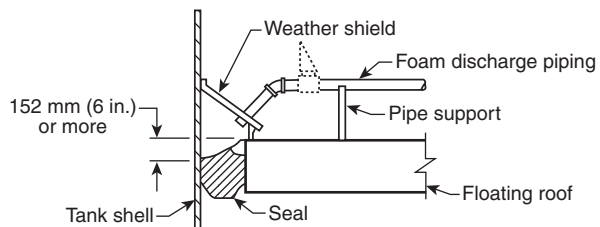
DETAIL A — Top-of-seal application
Foam discharge above mechanical shoe seal



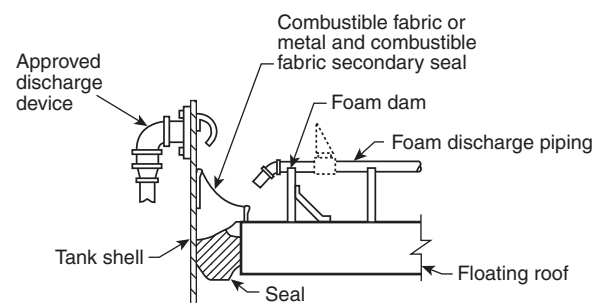
DETAIL A — Below-the-seal application
Foam discharge below mechanical shoe seal — no foam dam



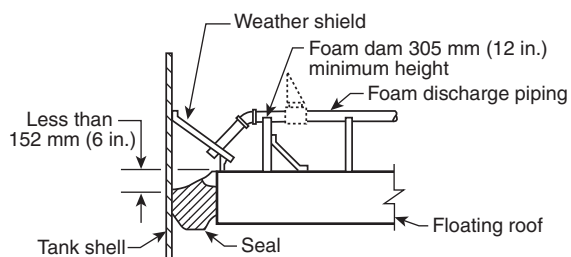
DETAIL B — Top-of-seal application
Foam discharge above metal weather shield



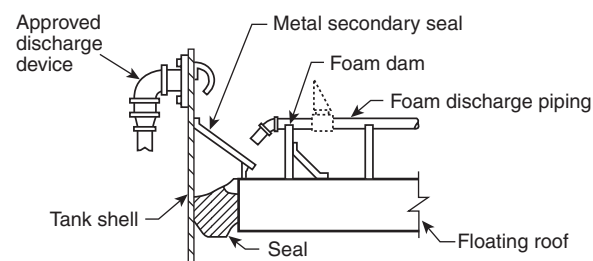
DETAIL B — Below-the-shield application
Foam discharge below metal weather shield
Top of seal 152 mm (6 in.) or more below top of floating roof



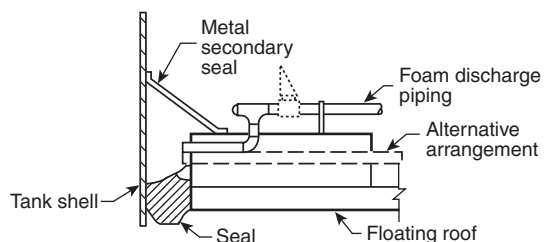
DETAIL C — Top-of-seal application
Foam discharge above secondary combustible fabric seal, or metal with combustible fabric sections



DETAIL C — Below-the-shield application
Foam discharge below metal weather shield
Top of seal less than 152 mm (6 in.) below top of floating roof



DETAIL D — Top-of-seal application
Foam discharge above metal secondary seal



DETAIL D — Below-the-seal application
Foam discharge below metal secondary seal
This foam application method is not acceptable if secondary seal is constructed of any combustible fabric sections.
(Refer to application above seal.)

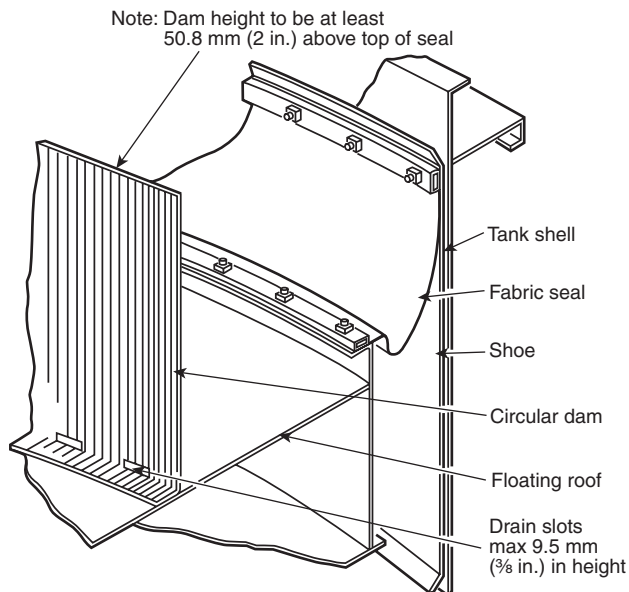
FIGURE 5.3.5.3.1 Typical Foam System Illustrations for Top-of-Seal Fire Protection. Both fixed foam (wall-mounted) and roof-mounted discharge outlets are shown for illustrative purposes. Although both methods are shown, only one is needed.

FIGURE 5.3.5.3.5.1 Typical Foam System Arrangement Illustrations for Below-the-Seal (or Shield) Application.

Table 5.3.5.3.6.1 Below-the-Seal Fixed Foam Discharge Protection for Open-Top Floating Roof Tanks

Seal Type	Applicable Illustration Detail	Minimum Application Rate		Minimum Discharge Time (minutes)	Maximum Spacing Between Discharge Outlets
		L/min · m ²	gpm/ft ²		
Mechanical shoe seal	A	20.4	0.5	10	39 m (130 ft) — Foam dam not required
Tube seal with more than 152 mm (6 in.) between top of tube and top of pontoon	B	20.4	0.5	10	18 m (60 ft) — Foam dam not required
Tube seal with less than 152 mm (6 in.) between top of tube and top of pontoon	C	20.4	0.5	10	18 m (60 ft) — Foam dam required
Tube seal with foam discharge below metal secondary seal*	D	20.4	0.5	10	18 m (60 ft) — Foam dam not required

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

**FIGURE 5.3.5.4.5 Typical Foam Dam for Floating Roof Tank Protection.**

- (3) Full liquid surface contact, metallic sandwich panel, conforming to Appendix H, "Internal Floating Roofs," requirements of API 650
- (4)*Full liquid surface contact, composite sandwich roof/seal system, designed in accordance with the performance cri-

teria in Appendix H, "Internal Floating Roofs," requirements of API 650 and the following:

- (a) Fiberglass components shall be made from high-grade vinyl ester resin with a corrosion-resistant bottom surface and be compatible with the stored product.
- (b) Top layer shall provide flame spread properties in accordance with ASTM E84 flame spread Class A rating.
- (c) The structural laminate of the composite sandwich structure shall be in accordance with ASTM C582.
- (d) Core material shall be of a closed-cell structure for inherent redundant buoyancy and shall be chemically compatible with the stored product.
- (e) The roof surfaces shall be a seamless, one-piece construction that utilizes chemical bonds to join all components.
- (f) The perimeter seal system shall be gas-tight and utilize noncombustible material to cover the rim space.

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

5.4.2.2 Design for Full Surface Fire.

5.4.2.2.1 Where the basis for design is a full surface fire, the covered (internal) floating roof tank shall be treated as equivalent to a fixed-roof (cone) tank of the same diameter for the purpose of foam system design.

5.4.2.2.2 For a full surface fire, the foam facilities shall be designed in accordance with 5.2.5 and Section 5.9, except that separately valved laterals for each foam discharge shall not be required.

5.4.2.2.3 For this application, fixed foam discharge outlets shall not be fitted with a frangible vapor seal device.

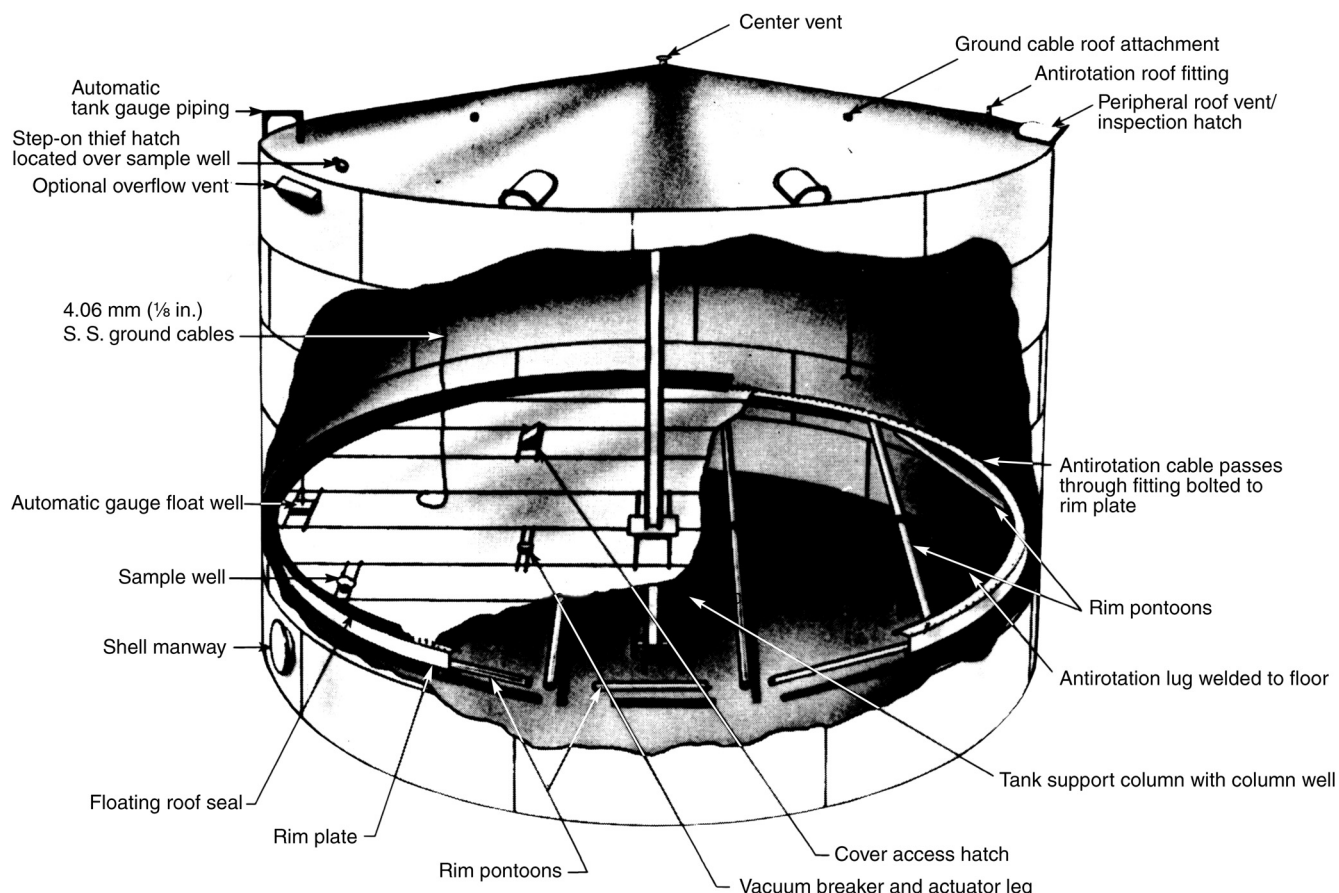


FIGURE 5.4 Typical Covered Floating Roof Tank.

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

5.4.2.3 Design for Seal Area Fire.

5.4.2.3.1 Where the basis for design is a seal fire, the covered (internal) floating roof tank shall be treated as equivalent to an open-top floating roof tank of the same diameter for the purpose of foam system design.

5.4.2.3.2 For a seal fire, the foam discharge system shall be designed in accordance with the requirements specified in Table 5.3.5.3.1 utilizing fixed foam discharge outlets.

5.4.2.3.3 Supplementary Protection. In addition to the primary means of protection, there shall be provisions for supplementary protection in accordance with the requirements of Section 5.9.

5.4.2.3.4* Basis of Design.

5.4.2.3.4.1 System design shall be based on protecting the tank requiring the largest solution flow, including supplementary hose streams.

5.4.2.3.4.2 If the application rate is higher than the minimum rate specified in Table 5.2.6.5.1, the discharge time shall be permitted to be reduced proportionately, but shall not be less than 70 percent of the minimum discharge times specified.

5.5 Indoor Hazards.

5.5.1* This section shall address foam fire-extinguishing systems, which are intended to protect indoor storage tanks that have liquid surface areas of 37.2 m² (400 ft²) or greater.

5.5.2 Discharge Outlets. Tanks for storing liquid hydrocarbons shall be fitted with Type II, tank-mounted fixed foam discharge outlets as specified in Table 5.2.6.2.8.

5.5.3 Minimum Discharge Time and Application Rate.

5.5.3.1 The minimum application rate for indoor hydrocarbon storage tanks shall be 6.5 L/min·m² (0.16 gpm/ft²) of liquid surface area.

5.5.3.2 Minimum discharge time shall be as specified in Table 5.2.5.2.2 for Type II fixed foam discharge outlets.

5.5.3.3 If the application rate is higher than the minimum rate specified in 5.5.2, the discharge time shall be permitted to be reduced proportionately, but not to less than 70 percent of the minimum discharge times indicated.

5.5.4 Design Criteria for Indoor Storage Tanks Containing Flammable or Combustible Liquids Requiring Alcohol-Resistant Foams.

5.5.4.1* Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to nonalcohol-resistant foams shall require the use of alcohol-resistant foams.



5.5.4.2 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.

5.6* Loading Racks.

5.6.1 Within the scope of this standard, loading racks shall be defined as being either truck or rail car types for the purpose of loading or unloading product.

5.6.2 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 factored into the design of a loading rack foam system.

5.6.3 Methods of Protection. The following shall be permitted to be two methods of protecting loading racks:

- (1) Foam-water sprinkler application utilizing air-aspirating foam-water sprinklers or nozzles or non-air-aspirating standard sprinklers
- (2) Foam monitors

5.6.4 Design Criteria for Foam-Water Sprinkler Systems. The design criteria for sprinkler systems shall be in accordance with NFPA 16.

5.6.5 Design Criteria for Foam Monitor Protection Systems.

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

5.6.5.2* 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.

5.6.5.3 Minimum Application Rates and Discharge Times.

5.6.5.3.1 Minimum foam application rates and discharge times for loading racks protected by monitor nozzles shall be as specified in Table 5.6.5.3.1.

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

5.7* Diked Areas — Outdoor.

5.7.1 For the purpose of this standard, diked areas shall be areas bounded by contours of land or physical barriers that retain a fuel to a depth greater than 25.4 mm (1 in.).

5.7.2 Protection of these areas shall be achieved by either fixed discharge outlets, fixed or portable monitors, or foam hoselines.

5.7.3 Methods of Application. Where foam protection is used for a diked area, it shall be permitted to be accomplished by any of the following methods:

- (1) Low-level foam discharge outlets
- (2) Foam monitors or foam hoselines
- (3) Foam-water sprinklers or nozzles

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

5.7.3.2 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 5.7.3.2.

5.7.3.3* Fixed Foam Discharge Outlets.

5.7.3.3.1 Fixed foam discharge outlets shall be sized and located to apply foam uniformly over the dike area at the application rate specified in Table 5.7.3.2.

5.7.3.3.2 Large dike areas shall be permitted to be subdivided to keep the total design solution within practical limits.

5.7.3.4 Fixed Foam-Water Sprinklers or Nozzles.

5.7.3.4.1 Where fixed foam-water sprinklers or nozzles are used, the system design shall be in accordance with NFPA 16.

5.7.3.4.2* Where foam-water sprinklers or nozzles are used as the primary protection, the design shall include the possibility that some of the foam discharge will be carried by the wind beyond the area of the fuel spill.

5.7.3.5 Fixed Low-Level Foam Discharge Outlets.

5.7.3.5.1 Fixed low-level foam discharge 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.

Table 5.6.5.3.1 Minimum Application Rates and Discharge Times for Loading Racks Protected by Foam Monitor Nozzle Systems

Foam Type	Minimum Application Rate		Minimum Discharge Time (minutes)	Product Being Loaded
	L/min · m ²	gpm/ft ²		
Protein and fluoroprotein	6.5	0.16	15	Hydrocarbons
AFFF, FFFP, and alcohol-resistant AFFF or FFFP	4.1	0.10	15	Hydrocarbons
Alcohol-resistant foams	Consult manufacturer for listings on specific products		15	Flammable and combustible liquids requiring alcohol-resistant foam

Table 5.7.3.2 Minimum Application Rates and Discharge Times for Fixed Foam Application on Diked Areas Involving Hydrocarbon Liquids

Type of Foam Discharge Outlets	Minimum Application Rate		Minimum Discharge Time (minutes)	
	L/min · m ²	gpm/ft ²	Class I Hydrocarbon	Class II Hydrocarbon
Low-level foam discharge outlets	4.1	0.10	30	20
Foam monitors	6.5	0.16	30	20

5.7.3.5.2 Fixed low-level foam discharge outlets shall be located around the dike wall, and, where necessary, inside the dike area, to apply foam uniformly over the dike area.

5.7.3.5.3* Limitations.

5.7.3.5.3.1 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 9 m (30 ft) from a discharge outlet where the discharge per outlet is 225 L/min (60 gpm) or less.

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

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

5.7.3.5.4.1 Where foam monitors are used as the primary protection, the design shall include the possibility that some of the foam discharge will be carried by the wind beyond the area of the fuel spill.

5.7.3.5.4.2 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.

5.7.4 Diked Areas Involving Flammable or Combustible Liquids Requiring Alcohol-Resistant Foams.

5.7.4.1 Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to nonalcohol-resistant foams shall require the use of alcohol-resistant foams.

5.7.4.2 Systems using these foams shall require special engineering consideration.

5.7.4.3 The design criteria for diked areas involving flammable or combustible liquids requiring alcohol-resistant foams shall be as stated in 5.7.4.3.1 through 5.7.4.3.3.

5.7.4.3.1 Methods of fixed protection shall be the same as those described in 5.7.3.3 for hydrocarbon hazards.

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

5.7.4.3.3 The minimum discharge time shall be 30 minutes.

5.8* Nondiked Spill Areas.

5.8.1 Design Criteria for Protection of Spill Fires Involving Hydrocarbons or Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams.

5.8.1.1 To determine protection for spill fires, the potential spill area shall be estimated.

5.8.1.2 Once this area has been determined, Table 5.8.1.2 shall be used to calculate requirements to be used as design criteria for portable nozzles or monitors.

5.9* Supplementary Protection.

5.9.1 Additional Protection. In addition to the primary means of protection, some types of hazards shall require provisions for supplemental means of protection.

5.9.2 Supplemental Foam Hose Stream Requirements.

5.9.2.1 Approved foam hose stream equipment shall be provided in addition to tank foam installations as supplementary protection for small spill fires.

Table 5.8.1.2 Minimum Application Rates and Discharge Times for Nondiked Spill Fire Protection Using Portable Foam Nozzles or Monitors

Foam Type	Minimum Application Rate		Minimum Discharge Time (minutes)	Anticipated Product Spill
	L/min · m ²	gpm/ft ²		
Protein and fluoroprotein	6.5	0.16	15	Hydrocarbon
AFFF, FFFP, and alcohol-resistant AFFF or FFFP	4.1	0.10	15	Hydrocarbon
Alcohol-resistant foams	Consult manufacturer for listings on specific products		15	Flammable and combustible liquids requiring alcohol-resistant foam



5.9.2.2 The minimum number of fixed or portable hose streams required shall be as specified in Table 5.9.2.2 and shall provide protection of the area.

Table 5.9.2.2 Supplemental Foam Hose Stream Requirements Diameter of Largest Tank

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

5.9.2.3 The equipment for producing each foam stream shall have a solution application rate of at least 189 L/min (50 gpm), with the minimum number of hose streams shown in Table 5.9.2.2.

5.9.2.4 Additional foam-producing materials shall be provided to allow operation of the hose stream equipment simultaneously with tank foam installations as specified in Table 5.9.2.4.

Table 5.9.2.4 Hose Stream Operating Times, Supplementing Tank Foam Installations

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

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

Chapter 6 Medium- and High-Expansion Systems

6.1* General Information and Requirements. This chapter shall apply to requirements for a design of medium- and high-expansion foam systems.

6.2 Use and Limitations.

6.2.1 Medium- and high-expansion foams shall be specifically evaluated to verify the applicability of medium- or high-expansion foam as a fire control agent for the type of hazard.

6.3* Hazards Protected. Hazards that medium- and high-expansion foam systems shall be permitted to protect include the following:

- (1) Ordinary combustibles
- (2) Flammable and combustible liquids
- (3) Combinations of (1) and (2)
- (4) Liquefied natural gas (high-expansion foam only)

6.3.1 Susceptibility of the protected hazard to water damage shall be evaluated.

6.3.2* Medium- and high-expansion foam systems shall not be used on fires in the following hazards except where component evaluation, including tests, indicates acceptability:

- (1) Chemicals, such as cellulose nitrate, that release oxygen or other oxidizing agents to sustain combustion
- (2) Energized unenclosed electrical equipment
- (3) Water-reactive metals such as sodium, potassium, and NaK (sodium-potassium alloys)
- (4) Hazardous water-reactive materials, such as triethylaluminum and phosphorus pentoxide
- (5) Liquefied flammable gas

6.4 Types of Systems. The types of systems within the scope of this standard shall be provided as follows:

- (1) Total flooding systems
- (2) Local application systems
- (3) Portable foam-generating devices

6.5 Systems Protecting One or More Hazards.

6.5.1 Systems shall be permitted to be used to protect one or more hazards or groups of hazards by means of the same supply of foam concentrate and water.

6.5.2 Where, in the opinion of the AHJ, two or more hazards can be simultaneously involved in fire by reason of their proximity, each hazard shall be protected with an individual system, or the system shall be arranged to discharge on all potentially involved hazards simultaneously.

6.6* Personnel Safety.

6.6.1* Where possible, the location of foam discharge points relative to building exits shall be arranged to facilitate evacuation of personnel.

6.6.1.1* To re-enter a foam-filled building, a coarse water spray shall be permitted to be used to cut a path in the foam. Personnel shall not enter the foam.

6.6.1.2* A canister-type gas mask shall not be worn in the foam.

6.6.1.2.1 If emergency reentry is essential, self-contained breathing apparatus shall be used in conjunction with a life-line.

6.6.1.3 Unenclosed electrical apparatus shall be de-energized upon system actuation unless it has been deemed unnecessary by competent evaluation.

6.6.2* Electrical Clearances.

6.6.2.1 All system components shall be located to maintain minimum clearances from live parts as shown in Table 6.6.2.1.

6.6.2.2 The clearances given are for altitudes of 1000 m (3281 ft) or less.

6.6.2.2.1* At altitudes in excess of 1000 m (3281 ft), the clearance shall be increased at the rate of 1 percent for each 100 m (328 ft) increase in altitude above 1000 m (3281 ft).

6.6.2.2.2 To coordinate the required clearance with the electrical design, the design BIL of the equipment being protected shall be used as a basis, although this is not material at nominal line voltages of 161 kV or less.

6.6.2.2.3 At voltages higher than 161 kV, uniformity in the relationship between design BIL kV and the various electrical system voltages has not been established in practice and is dependent on several variables; thus, the required clearances to ground shall be based on the design BIL used rather than on the nominal line or ground voltage.

Table 6.6.2.1 Clearance from Medium- and High-Expansion Foam Equipment to Live Uninsulated Electrical Components

Nominal Line Voltage (kV)	Nominal Voltage to Ground (kV)	Design BIL* (kV)	Minimum Clearance	
			mm	in.
To 15	To 9	110	178	7
23	13	150	254	10
34.5	20	200	330	13
46	27	250	432	17
69	40	350	635	25
115	66	550	940	37
138	80	650	1118	44
161	93	750	1321	52
196-230	114-132	900	1600	63
		1050	1930	76
		1175	2210	87
		1300	2489	98
287-380	166-220	1425	2769	109
		1550	3048	120
500	290	1675	3327	131
		1800	3607	142
		1925	3886	153
500-700	290-400	2100	4267	168
		2300	4674	184

*Basic insulation level (BIL) values are expressed as kilovolts (kV), the number being the crest value of the full wave impulse test that the electrical equipment is designed to withstand.

6.6.2.2.4 The clearance between uninsulated energized parts of the electrical system equipment and any portion of the medium- or high-expansion foam system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

6.7 Operation and Control of Systems.

6.7.1* Detection of Fires.

6.7.1.1 Automatic detection shall be used for fixed systems.

6.7.1.1.1* Removal of automatic detection shall be permitted when approved by the AHJ.

6.7.1.2* Automatic detection shall be by listed or approved methods or devices capable of detection and indicating heat, smoke, or flame. Automatic detection devices shall be installed in accordance with *NFPA 72*.

6.7.1.3 Detection by the use of combustible vapor detectors or an abnormal condition in the hazard, such as process trouble, shall be arranged using approved industrial practices as specified by an engineering study.

6.7.1.4* A reliable source of energy shall be used in detection systems.

6.7.1.4.1 The power supply for electrical detection systems shall be independent of the supply for the protected area.

6.7.1.4.2 Arrangement of the power supply shall be in accordance with requirements of *NFPA 72* for continuity of power supplies.

6.7.2 Supervision. Supervision of automatic detection and actuation equipment shall be provided and arranged so that

there will be an immediate indication of failure, preferably at a constantly attended location.

6.7.3 Alarms.

6.7.3.1 Audible alarms shall be installed to indicate the operation of the system, to alert personnel, and to indicate failure of any supervised device or equipment.

6.7.3.2 Such devices shall be of such a type and shall be provided in such numbers and at such locations as are necessary to accomplish their purpose satisfactorily.

6.7.3.3 An alarm shall be provided to show that the system has operated.

6.7.3.4 Alarms shall be provided to give ample warning of discharge where hazard(s) to personnel exist.

6.7.3.5 Alarms indicating failure of supervised devices or equipment shall give prompt and positive indication of any failure and shall be distinctive from alarms indicating operation or hazardous conditions.

6.7.4* Operating Devices.

6.7.4.1 Operating devices shall include foam generators, valves, proportioners, eductors, discharge controls, and shut-down equipment.

6.7.4.1.1 Operation shall be controlled by listed or approved mechanical, electrical, hydraulic, or pneumatic means.

6.7.4.1.2 A reliable source of energy shall be used.

6.7.4.1.3 The electrical power supply for an electrically operated medium- or high-expansion foam system shall be as reliable as a fire pump circuit in accordance with *NFPA 20*.

6.7.4.2 All operating devices shall be approved for the service they will encounter and shall not be rendered inoperative or susceptible to accidental operation.

6.7.4.2.1 Provision shall be made to protect piping that is normally filled with liquid from freezing.

6.7.4.3 All devices shall be located, installed, or suitably protected so that they are not subject to mechanical, chemical, climatic, or other conditions that will render them inoperative.

6.7.4.4 Manual controls for actuation and shutdown shall be conveniently located and accessible at all times, including the time of fire and system operation.

6.7.4.4.1 Remote control stations for manual actuation shall be considered where the area is large, where egress is difficult, or where required by the AHJ.

6.7.4.4.2 Manual controls for actuation shall operate the system to the same extent as the automatic control.

6.7.4.5 All automatically operated equipment controlling the generation and distribution of foam shall be provided with approved independent means for emergency manual operation.

6.7.4.5.1 If the means for manual actuation of the system required in 6.7.1 provide approved positive operation independent of the automatic actuation, it shall be permitted to be used as the emergency means.

6.7.4.5.2 The emergency means, preferably mechanical, shall be accessible and located close to the equipment controlled.



6.7.4.5.3 If possible, the system shall be designed so that complete emergency actuation shall be permitted to be accomplished from one location.

6.7.4.6 All required door and window closers, vent openers, and electrical equipment shutdown devices shall be considered integral parts of the system and shall function simultaneously with the system operation.

6.7.4.7 All manual operating devices shall be identified with signs as to the hazards they protect.

6.8 Foam Concentrate.

6.8.1 Quality. (*See Annex G.*)

6.8.1.1 The foam concentrate used in the system shall be listed for use with the equipment.

6.8.1.2 The quality of the concentrate for performance under the installation requirements of this standard shall be determined by tests.

6.9 Air Supply.

6.9.1 Air from outside the hazard area shall be used for foam generation unless data is provided to show that air from inside the hazard can be successfully employed.

6.9.2 The data shall be specific for the products of combustion to be encountered and shall provide factors for increasing foam discharge rates over those given in 6.12.8 if fire tests indicate that need.

6.9.3 Vents from the fire area shall be located to prevent recirculation of combustion products or other materials deleterious to the formation of foam into foam generator air inlets.

6.10 Foam-Generating Apparatus Location.

6.10.1 Accessibility for Inspection and Maintenance. Foam-generating apparatus shall be located and arranged so that inspection, testing, recharging, and other maintenance is facilitated and interruption of protection is held to a minimum.

6.10.2* Protection Against Exposure.

6.10.2.1 Foam-generating equipment shall be located as close as possible to the hazard(s) it protects, but not where it will be unduly exposed to a fire or explosion.

6.10.2.2 Foam generators installed inside the hazard area shall be listed to resist or be protected against fire exposure for the duration of the fire.

6.10.2.3 Such protection shall be permitted to be in the form of insulation, water spray or sprinklers, or other method as determined by an engineering study.

6.10.2.4 In certain applications, additional generators shall be permitted to be substituted for fire exposure protection based on results of fire tests.

6.11 Distribution Systems.

6.11.1 Piping and Fittings. Piping and fittings shall conform to the requirements of Chapter 4.

6.11.2 Arrangement and Installation of Piping and Fittings.

6.11.2.1 A listed strainer for use with the proportioner and foam generator shall be provided in the water line upstream of the water valve.

6.11.2.2 Supplemental strainers shall be permitted to be used as recommended by the foam equipment manufacturer.

6.11.3 Ducts.

6.11.3.1 Foam distribution and air inlet ducts shall be designed, located, installed, and suitably protected so that they are not subject to undue mechanical, chemical, or other damage.

6.11.3.2 Duct closures such as selector valves, gates, or doors shall be of the quick-opening type, so as to allow free passage of the foam.

6.11.3.2.1 When duct closures are located where they are subjected to fire or heat exposure, either inside or outside the area to be protected, special care shall be taken to ensure positive operation.

6.11.3.3 Ducts shall be designed and installed so that undue turbulence is avoided, and the actual foam discharge rate shall be determined by test or other method acceptable to the AHJ.

6.12 Total Flooding Systems General Information.

6.12.1 Description. A total flooding system shall consist of fixed foam-generating apparatus complete with a piped supply of foam concentrate and water, arranged to discharge into an enclosed space or enclosure around the hazard.

6.12.2* Applications. Total flooding systems shall be permitted to be used where a permanent enclosure is provided around the hazard to enable the required amount of fire-extinguishing medium to accumulate at the proper depth and to be maintained for a period of time required to ensure fire control or extinguishment in a specific combustible material.

6.12.3 General Requirements.

6.12.3.1 Total flooding systems shall be designed, installed, tested, and maintained in accordance with the applicable requirements of this standard.

6.12.3.2 Only listed or approved equipment and devices shall be used in these systems.

6.12.4 Total Flooding Enclosure Specifications.

6.12.4.1* Leakage.

6.12.4.1.1 Openings. Openings below design filling depth, such as doorways and windows, shall be arranged to close automatically before, or simultaneously with, the start of the foam discharge, with due consideration for evacuation of personnel.

6.12.4.1.1.1 Openings shall be designed to maintain closure during a fire and shall be capable of withstanding pressures of foam and sprinkler water discharge.

6.12.4.1.1.2 Where openings cannot be protected by automatic closing devices, the total flooding system shall be designed to compensate for the probable loss of foam.

(A) The system design shall be tested to ensure proper performance.

(B) If the foam system is permitted to start prior to complete closure of the space to be filled, additional foam output shall be allowed to compensate for the losses.

(C) This shall be verified by test based on the individual site conditions.

6.12.4.1.2 Ventilation.

6.12.4.1.2.1 Where outside air is used for foam generation, high-level venting shall be provided for air that is displaced by the foam.

6.12.4.1.2.2 Venting velocity shall not exceed 305 m/min (1000 ft/min) in free air.

6.12.4.1.2.3 The required venting shall consist of openings, either normally open or normally closed and arranged to open automatically when the system operates.

6.12.4.1.2.4 Where design criteria demand exhaust fans, they shall be approved for high-temperature operation and installed with consideration for protection of switches, wiring, and other electrical devices to ensure equal reliability of exhaust fan performance. Operation of the fans shall not compromise foam generator operations.

6.12.4.1.2.5 Where forced-air ventilating systems interfere with the proper buildup of foam, they shall be automatically shut down or closed.

6.12.5 Foam Requirements.

6.12.5.1 General. Total flooding medium- or high-expansion foam shall be discharged at a rate required to fill the enclosure to a depth above the hazard before an unacceptable degree of damage occurs.

6.12.5.2 Foam Depth.

6.12.5.2.1 High-Expansion Foam.

6.12.5.2.1.1 The minimum total depth of foam shall be not less than 1.1 times the height of the highest hazard but in no case less than 0.6 m (2 ft) over this hazard.

6.12.5.2.1.2 For flammable or combustible liquids, the required depth over the hazard shall be permitted to be considerably greater than the requirement of 6.12.5.2.1.1 and shall be no less than the depth determined by tests. Tests shall duplicate the anticipated fire event in the protected area.

6.12.5.2.2 Medium-Expansion Foam.

6.12.5.2.2.1 Required depth over the hazard shall vary with expansion.

6.12.5.2.2.2 Depth shall be determined by tests. (See 6.12.6.3 and Annex G.)

6.12.6 Submergence Volume for High-Expansion Foams.

6.12.6.1 Submergence volume for sprinkler protected areas shall be defined as the depth as specified in 6.12.5.2.2.2 multiplied by the floor area of the space to be protected in accordance with 6.12.3.

6.12.6.2 Submergence volume for unsprinklered rooms of combustible construction or finish shall be based on the entire volume, including concealed spaces.

6.12.6.3 The volume occupied by vessels, machinery, or other permanently located equipment shall be permitted to be deducted when determining the submergence volume.

6.12.6.4 The volume occupied by stored material shall not be deducted when determining the submergence volume.

6.12.7 Submergence Time for High-Expansion Foams.

6.12.7.1* Recommended times to achieve submergence volume for various types of hazards and building construction shall be as shown in Table 6.12.7.1 and in accordance with NFPA 220, Table 4.1.1.

6.12.7.2 Shorter submergence times shall be permitted to be required depending on the factors included in 6.12.8.

6.12.7.3 The submergence time shall be based on a maximum of 30 seconds delay between fire detection and start of foam discharge.

6.12.7.4 Any delays in excess of 30 seconds shall be deducted from the submergence times in Table 6.12.7.1.

6.12.7.5 Where use of high-expansion foam on polar solvents is contemplated, the foam equipment supplier shall substantiate suitability for the intended use.

6.12.8* Rate of Discharge.

6.12.8.1 Medium-Expansion Foam. The rate of discharge for medium-expansion foam shall be determined by tests.

6.12.8.2 High-Expansion Foam.

6.12.8.2.1* The rate of foam discharge necessary for extinguishment or control to permit overhaul shall be dependent on the strength of sprinkler protection, the nature and configuration of the hazard, the vulnerability of the structure and contents to fire, and the loss potential to life, property, and production.

6.12.8.2.2 The foam discharge rate shall meet the foam depth requirements and submergence times of Table 6.12.7.1, with compensation for normal foam shrinkage, foam leakage, and breakdown effects of sprinkler discharge.

6.12.8.2.3 Calculation.

6.12.8.2.3.1* The minimum rate of discharge or total generator capacity shall be calculated from the following formula:

$$R = \left(\frac{V}{T} + R_s \right) \times C_N \times C_L \quad [6.12.8.2.3.1]$$

where:

R = rate of discharge in m³/min (ft³/min)

V = submergence volume in m³ (ft³)

T = submergence time in minutes

R_s = rate of foam breakdown by sprinklers in m³/min (ft³/min)

C_N = compensation for normal foam shrinkage

C_L = compensation for leakage

6.12.8.2.3.2* The factor (R_s) for compensation for breakdown by sprinkler discharge shall be determined either by test or, in the absence of specific test data, by the following formula:

$$R_s = S \times Q \quad [6.12.8.2.3.2]$$

where:

S = foam breakdown in m³/min · L/min (ft³/min · gpm) of sprinkler discharge.

S shall be 0.0748 m³/min · L/min (10 ft³/min · gpm)

Q = estimated total discharge from maximum number of sprinklers expected to operate in L/min (gpm)

6.12.8.2.3.3 The factor (C_N) for compensation for normal foam shrinkage shall be 1.15, which is an empirical factor based on average reduction in foam quantity from solution drainage, fire, wetting of surfaces, absorbency of stock, and so forth.

6.12.8.2.3.4* The factor (C_L) for compensation for loss of foam due to leakage around doors and windows and through unclosable openings shall be determined by the design engineer after evaluation of the structure. This factor shall not be



Table 6.12.7.1 Maximum Submergence Time for High-Expansion Foam Measured from Start of Foam Discharge in Minutes

Hazard	Construction Type			
	Type II (000), Type III (200), Type V (000)		Type I (all), Type II (222, 111), Type IV (2HH), Type V (111)	
	Sprinklered	Not Sprinklered	Sprinklered	Not Sprinklered
Flammable liquids [flash points below 38°C (100°F)] having a vapor pressure not exceeding 276 kPa (40 psia)	3	2	5	3
Combustible liquids [flash points of 38°C (100°F) and above]*	4	3	5	3
Low-density combustibles (i.e., foam rubber, foam plastics, rolled tissue, or crepe paper)	4	3 [†]	6	4 [†]
High-density combustibles (i.e., rolled paper kraft or coated banded)	7	5 [†]	8	6 [†]
High-density combustibles (i.e., rolled paper kraft or coated unbanded)	5	4 [†]	6	5 [†]
Rubber tires	7	5 [†]	8	6 [†]
Combustibles in cartons, bags, or fiber drums	7	5 [†]	8	6 [†]

*Polar solvents are not included in this table. Flammable liquids having boiling points lower than 38°C (100°F) might require higher application rates. See NFPA 30.

[†]These submergence times might not be directly applicable to storage piled above 4.6 m (15 ft) or where fire spread through combustible contents is very rapid.

permitted to be less than 1.0 even for a structure completely tight below the design filling depth. This factor shall be permitted to be as high as 1.2 for a building with all openings normally closed, depending on foam expansion ratio, sprinkler operation, and foam depth.

6.12.9 Quantity.

6.12.9.1 High-expansion foam concentrate and water shall be provided to permit continuous operation of the entire system for 25 minutes or to generate four times the submergence volume, whichever is less, but in no case less than enough for 15 minutes of full operation.

6.12.9.2 The quantity for medium-expansion foam shall be determined by tests developed by an independent testing laboratory.

6.12.9.3 Reserve supplies shall be provided in accordance with 6.12.9.

6.12.10* Maintenance of Submergence Volume for High-Expansion Foam.

6.12.10.1 To ensure control or extinguishment, the submergence volume shall be maintained for at least 60 minutes for unsprinklered locations and 30 minutes for sprinklered locations.

6.12.10.2 Where the hazard consists of flammable or combustible liquids in noncombustible containers, the time in 6.12.10.1 shall be permitted to be reduced.

6.12.10.3 Method.

6.12.10.3.1 The submergence volume shall be permitted to be maintained by continuous or intermittent operation of any or all of the generators provided.

6.12.10.3.2* Arrangements and procedures shall be provided to maintain the submergence volume without waste of foam concentrate.

6.12.10.4* Overhaul. Overhaul procedures shall be preplanned to prevent loss of control by submergence of the hazard.

6.12.10.5 Distribution. The medium- and high-expansion foam generators shall be located such that a relatively even buildup of foam will take place throughout the protected area during the discharge period.

6.13 Local Application Systems.

6.13.1 General Information.

6.13.1.1 Description. A local application system shall consist of fixed foam-generating apparatus complete with a piped supply of foam concentrate and water that is arranged to discharge foam directly onto a fire or spill hazard.

6.13.1.2* Uses.

6.13.1.2.1 Local application systems shall be permitted to be used for the extinguishment or control of fires in flammable or combustible liquids, liquefied natural gas (LNG), and ordinary Class A combustibles where the hazard is not totally enclosed.

6.13.1.2.2 For multiple-level or three-dimensional fire hazards where total building flooding is impractical, the individual hazard shall be provided with containment facilities.

6.13.2 General Requirements.

6.13.2.1 Local application systems shall be designed, installed, tested, and maintained in accordance with the applicable requirements in this standard.

6.13.2.2 Only listed or approved equipment, devices, and agents shall be used in these systems.

6.13.3 Hazard Specifications.

6.13.3.1 Extent of Hazard. The hazard shall include all areas to or from which fire shall spread.

6.13.3.2* Location of Hazard.

6.13.3.2.1 Local application medium- and high-expansion foam systems shall be permitted to be used to protect hazards located indoors, under partial shelter, or completely outdoors.

6.13.3.2.2 Provisions shall be made to compensate for winds and other effects of weather.

6.13.3.3 Foam Requirements for Flammable and Combustible Liquids and Solids.

6.13.3.3.1 General. Foam shall be discharged at a rate to cover the hazard to a depth of at least 0.6 m (2 ft) within 2 minutes.

6.13.3.3.2 Quantity.

6.13.3.3.2.1 Foam concentrate and water shall be provided to permit continuous operation of the entire system for at least 12 minutes.

6.13.3.3.2.2 Reserve supplies shall be provided in accordance with 6.12.9.

6.13.3.3.3 Arrangement.

6.13.3.3.3.1 Discharge outlets shall be arranged to ensure that foam is delivered over all areas that constitute the hazard.

6.13.3.3.3.2 Where parts of the hazard are elevated or raised up from the ground or floor line, the arrangement of the system shall be such that foam will be delivered to, and retained on, such parts in the required depth to ensure prompt and final extinguishment.

6.14* Foam Applications for Liquefied Natural Gas (LNG).

6.14.1* System Design Considerations.

6.14.1.1 The determination of the high-expansion foam system design shall depend on an analysis specific to the individual site.

6.14.1.2 The analysis shall include effects of heat exposure on adjacent plant equipment.

6.14.1.3 Automatic alarms and actuation shall be required for fixed systems.

6.14.1.3.1 Where an engineering study shows that automatic protection is not required, the system shall be permitted to be activated manually.

6.14.2* Foam Discharge Rate per Unit Area.

6.14.2.1 The discharge rate per unit area shall be established by tests and shall be able to achieve a positive and progressive reduction in radiation within the time limitations established in the analysis.

6.14.2.2 The discharge rate per unit area determined by the test in Section G.4 shall be increased by the necessary factor to account for the initial vaporization rate and the configuration of the hazard.

6.14.2.3 After steady-state control conditions have been reached, the discharge rate per unit area established in the test for maintenance of fire control shall be used to maintain control.

6.14.3 Quantity.

6.14.3.1 The initial quantity of foam concentrate shall permit a continuous application at the initial design rate for fire control to reach steady-state conditions.

6.14.3.2 Additional foam concentrate supplies shall be on hand to provide control maintenance for the calculated fire duration.

6.14.3.3* Foam System Arrangement. The foam system shall have foam outlets arranged to supply foam to cover the design fire area within the specified time.

6.15 Portable Foam-Generating Devices.

6.15.1 General Information.

6.15.1.1 Description.

6.15.1.1.1 Portable foam-generating devices consist of a foam generator, manually operable and transportable, connected by means of hose, or piping and hose, to a supply of water and foam concentrate.

6.15.1.1.2 The proportioning equipment shall be integral to or separate from the foam generator.

6.15.1.1.3 A separate foam concentrate supply shall be permitted to be provided for each unit, or solution shall be permitted to be piped from central proportioning equipment.

6.15.1.2 General Requirements.

6.15.1.2.1 Portable foam-generating devices and associated equipment shall be used and maintained in accordance with the applicable requirements in this standard.

6.15.1.2.2 Only listed or approved equipment and devices shall be used.

6.15.2 Hazard Specifications. Portable foam-generating devices shall be permitted to be used to combat fires in all hazards covered in this chapter.

6.15.3 Location and Spacing.

6.15.3.1 Portable foam-generating devices that are preconnected to a water or solution supply shall be placed where they are accessible and shall have enough hose to reach the most distant hazard they are expected to protect.

6.15.3.2 Foam concentrate shall be accessible for immediate use.

6.15.3.3 Portable foam generators shall be located such that they are not exposed to the hazard.

6.15.3.4 When portable foam generators are not preconnected to a water or solution supply, their associated equipment shall be located and arranged for immediate transport to all designated hazards.

6.15.4 Foam Requirements.

6.15.4.1 Rate and Duration of Discharge.

6.15.4.1.1 The rate and duration of discharge, and consequently the quantity of foam concentrate and water, shall be determined by the type and potential size of hazard.