NFPA 11

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

2002 Edition

NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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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 May Association Technical Meeting held May 19–23, 2002, in Minneapolis, MN. It was issued by the Standards Council on July 19, 2002, with an effective date of August 8, 2002, and supersedes all previous editions.

This edition of NFPA 11 was approved as an American National Standard on July 19, 2002.

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 have been included.

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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.

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

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

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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.

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

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

Chapter 1 Administration

1.1* Scope. This standard covers the design, installation, operation, testing, and maintenance of low-, medium-, and high-expansion foam systems for fire protection. It is not the intent of this standard to specify where foam protection is required.

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

1.3 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, Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems.)*
(3) Foam-water closed-head sprinkler systems *(See NFPA 16, Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems.)*
(4) Combined agent systems
(5) Mobile foam apparatus *(See NFPA 1901, Standard for Automotive Fire Apparatus.)*
(6) Class A foam and systems *(See NFPA 1150, Standard on Fire-Fighting Foam Chemicals for Class A Fuels in Rural, Suburban, and Vegetated Areas.)*

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 portion 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. Technical documents shall be submitted to the authority having jurisdiction to demonstrate equivalency. 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.

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 ASTM SI 10, *Standard for Metric Practice.*

Chapter 2 Referenced Publications

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

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

NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems,* 1999 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2002 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2001 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 1999 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 1999 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 2002 edition.

NFPA 70, *National Electrical Code®,* 2002 edition.

NFPA 72®, National Fire Alarm Code®, 2002 edition.

NFPA 1150, *Standard on Fire-Fighting Foam Chemicals for Class A Fuels in Rural, Suburban, and Vegetated Areas,* 1999 edition.

NFPA 1901, *Standard for Automotive Fire Apparatus,* 1999 edition.

2.3 Other Publications.

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

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

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

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

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

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

ANSI B16.9, *Factory-Made Wrought Steel Buttwelding Fittings*, 2001.

ANSI B16.11, *Forged Fittings, Socket-Welding and Threaded,* 2001.

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

2.3.2 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2958.

ASTM A 53, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, 2001.

ASTM A 105, *Standard Specification for Carbon Steel Forgings for Piping Applications*, 2001.

ASTM A 106, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*, 1999.

ASTM A 135, *Standard Specification for Electric Resistance-Welded Pipe*, 2001.

ASTM A 182, *Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*, 2001.

ASTM A 216, *Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service*, 1998.

ASTM A 234, *Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*, 2001.

ASTM A 312, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes*, 2001.

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*, 2000.

ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System*, 2001.

2.3.3 AWS Publication. American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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

2.3.4 API Publication. American Petroleum Institute, 120 L Street Northwest, Washington, DC 20005.

API 650, *Welded Steel Tanks for Oil Storage*, 1998.

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

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

2.3.6 IMO Publication. International Maritime Organization, 4 Albert Embankment, London SE1 7SR.

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

2.3.7 UL Publication. Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062.

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

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, 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. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

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

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

3.3.3 Discharge Device. A device designed to discharge water or foam-water solution in a predetermined, fixed, or adjustable pattern. Examples include, but are not limited to, sprinklers, spray nozzles, and hose nozzles.

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

3.3.6 Fire.

3.3.6.1 Class A. Fire in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.

3.3.6.2 Class B. Fire in flammable liquids, oils, greases, tars, oil base paints, lacquers, and flammable gases.

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

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

3.3.9 Flammable and Combustible Liquids. Flammable liquids shall be or shall include any liquids having a flash point below 37.8°C (100°F) and having a vapor pressure not exceeding 276 kPa (40 psi) (absolute) at 37.8°C (100°F). Flammable liquids shall be subdivided as follows: (1) Class I liquids shall include those having flash points below 37.8°C (100°F) and shall be subdivided as follows: a. Class IA liquids shall include those having flash points below 22.8°C (73°F) and having a boiling point below 37.8°C (100°F). b. Class IB liquids shall include those having flash points below 22.8°C (73°F) and having a boiling point above 37.8°C (100°F). c. Class IC liquids shall include those having flash points at or above 22.8°C (73°F) and below 37.8°C (100°F). Combustible liquids shall be or shall include any liquids having a flash point at or above 37.8°C (100°F). They shall be subdivided as follows: (1) Class II liquids shall include those having flash points at or above 37.8°C (100°F) and below 60°C (140°F); (2) Class IIIA liquids shall include those having flash points at or above 60°C (140°F) and below 93.3°C (200°F); (3) Class IIIB liquids shall include those having flash points at or above 93.3°C (200°F).

3.3.10 Foam. Fire-fighting foam, within the scope of this standard, is a stable aggregation of small bubbles of lower density than oil or water that exhibits a tenacity for covering horizontal surfaces. Air foam is made by mixing air into a water solution, containing a foam concentrate, by means of suitably designed equipment. It flows freely over a burning liquid surface and forms a tough, air-excluding, continuous blanket that seals volatile combustible vapors from access to air. It resists disruption from wind and draft or heat and flame attack and is capable of resealing in case of mechanical rupture. Fire-fighting foams retain these properties for relatively long periods of time. Foams also are defined by expansion and are arbitrarily subdivided into three ranges of expansion. These ranges correspond broadly to certain types of usage described below. The three ranges are as follows: (1) Low-expansion foam —expansion up to 20; (2) Medium-expansion foam—expansion from 20 to 200; (3) High-expansion foam—expansion from 200 to approximately 1000.

3.3.11 Foam Chamber. See Fixed Foam Discharge Outlet.

3.3.12 Foam Concentrate. Foam concentrate is a concentrated liquid foaming agent as received from the manufacturer. For the purpose of this document, "foam concentrate" and "concentrate" are used interchangeably.

3.3.12.1 Alcohol-Resistant Foam Concentrate. This concentrate is used for fighting fires on water-soluble materials and other fuels destructive to regular, AFFF, or FFFP foams, as well as for fires involving hydrocarbons. There are three general types. One is based on water-soluble natural polymers, such as protein or fluoroprotein concentrates, and also contains alcohol-insoluble materials that precipitate as an insoluble barrier in the bubble structure. The second type is based on synthetic concentrates and contains a gelling agent that surrounds the foam bubbles and forms a protective raft on the surface of water-soluble fuels; these foams can also have film-forming characteristics on hydrocarbon fuels. The third type is based on both water-soluble natural polymers, such as fluoroprotein, and contains a gelling agent that protects the foam from water-soluble fuels. This foam can also have film-forming and fluoroprotein characteristics on hydrocarbon fuels. Alcohol-resistant foam concentrates are generally used in concentrations of 3 to 10 percent solutions, depending on the nature of the hazard to be protected and the type of concentrate.

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

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

3.3.12.4 Fluoroprotein Foam Concentrate. Fluoroprotein-foam concentrate is very similar to protein-foam concentrate but has a synthetic fluorinated surfactant additive. In addition to an air-excluding foam blanket, they also can deposit a vaporization-preventing film on the surface of a liquid fuel. It is diluted with water to form 3 percent to 6 percent solutions depending on the type. This concentrate is compatible with certain dry chemicals.

3.3.12.5 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.

3.3.12.6 Other Synthetic Foam Concentrate. Other synthetic-foam concentrate is based on hydrocarbon surface active agents and is listed as a wetting agent, foaming agent, or both. In general, its use is limited to portable nozzle foam application for spill fires within the scope of their listings. The appropriate listings shall be consulted to determine proper application rates and methods.

3.3.12.7 Medium- and High-Expansion Foam Concentrate. This concentrate, which is usually derived from hydrocarbon surfactants, is used in specially designed equipment to produce foams having foam-to-solution volume ratios of 20:1 to approximately 1000:1. This equipment can be air-aspirating or blower-fan type.

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

3.3.12.9 Synthetic Foam Concentrate. Synthetic-foam concentrate is based on foaming agents other than hydrolyzed proteins and includes Aqueous Film-Forming Foam (AFFF) Concentrates, Medium- and High-Expansion Foam Concentrates, and Other Synthetic-Foam Concentrates.

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

3.3.13.1 Foam Generators — Aspirator Type. Foam generators can be fixed or portable. Jet streams of foam solution aspirate sufficient amounts of air that is then entrained on the screens to produce foam. These generators usually produce foam with expansion ratios of not more than 250:1.

3.3.13.2 Foam Generators — Blower Type. Foam generators can be fixed or portable. The foam solution is discharged as a spray onto screens through which an airstream developed by a fan or blower is passing. The blower can be powered by electric motors, internal combustion engines, air, gas, or hydraulic motors or water motors. The water motors are usually powered by foam solution.

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

3.3.15 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. They are constructed so that one or several streams of foam solution issue into a space with free access to air. Part of the energy of the liquid is used to aspirate air into the stream, and turbulence downstream of this point creates a stable foam capable of being directed to the hazard being protected. Various types of devices can be installed at the end of the nozzle to cause the foam to issue in a wide pattern or a compacted stream.

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

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

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

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

3.3.20 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.

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

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

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

3.3.24 Proportioning Methods for Air Foam Systems. The methods of proportioning used to create the proper solution of water and foam liquid concentrate recognized by this standard include: Coupled Water-Motor Pump, Foam Nozzle Eductor, Metered Proportioning, Pressure Proportioning Tank, and Pump Proportioner (Around-the-Pump Proportioner).

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

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

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

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

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

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

3.3.25 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.

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

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

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

Chapter 4 System Components and System Types

4.1 General.

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

4.1.2 All components shall be listed for their intended use.

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

4.2 Water Supplies.

4.2.1 Water Supplies, Including Premix Solution.

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

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

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 system shall be designed and installed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*.

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 sufficient number.

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

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, *Standard for the Installation of Stationary Pumps for Fire Protection*.

4.2.2.2 Controllers in accordance with NFPA 20 are not 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 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) Others listed for this purpose

4.3.1.5 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 authority having jurisdiction can permit 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 placing the equipment 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 be at least sufficient for the largest single hazard protected or group of hazards that are to be protected simultaneously.

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

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 authority having jurisdiction).

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 available from an approved outside source within 24 hours.

4.3.2.6 Auxiliary Supplies. Other equipment necessary to recommission the system, such as bottles of nitrogen or carbon dioxide for premix systems, also shall be available.

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 to and accepted by the authority having jurisdiction to prove that they are compatible.

4.4.1.3 Foams generated separately from protein, fluoroprotein, FFFP, and AFFF 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) Foam nozzle eductor
(2) In-line eductor
(3) Pressure proportioners
(4) Around-the-pump proportioners
(5) Direct pumping proportioners
(6) Metered proportioning
(7) Balanced pressure proportioners

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, *Standard for the Installation of Stationary Pumps for Fire Protection.*

4.6.2 Special attention shall be paid to the type of seal or packing used.

4.6.3 Foam concentrate pumps shall have adequate capacities to meet the maximum system demand.

4.6.3.1 To ensure positive injection of concentrates, the discharge pressure ratings of pumps at the design discharge capacity shall be in excess of the maximum water pressure available under any condition at the point of concentration injection.

4.7 Piping.

4.7.1 Pipe Materials. Pipe within the hazard area shall be of steel or other alloy rated for the pressure and temperature involved.

4.7.1.1 Steel pipe shall not be less than standard weight (Schedule 40 through nominal 12-in. diameter).

4.7.1.2 Steel pipe shall conform to one of the following standards:

(1) ASTM A 135, *Standard Specification for Electric Resistance-Welded Pipe*
(2) ASTM A 53, *Standard Specification for Pipe Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless*
(3) ASTM A 795, *Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use*

4.7.1.3 Pipe outside the hazard area shall conform to the materials allowed by NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances.*

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

4.7.1.5 Lightweight pipe [Schedule 10 in nominal sizes through 5 in.; 3.40-mm (0.134-in.) wall thickness for 6 in.; and 4.78-mm (0.188-in.) wall thickness for 8 in. and 10 in.] shall be permitted to be used in areas where fire exposure is improbable.

4.7.1.6 Selection of pipe wall thickness shall anticipate internal pressure, internal and external pipe wall corrosion, and mechanical bending requirements.

4.7.2 Foam System Piping.

4.7.2.1* Galvanized pipe shall be used for normally noncorrosive atmospheres.

4.7.2.2 Pipe carrying foam concentrate shall not be galvanized.

4.7.2.3 Piping in constant contact with foam concentrates shall be constructed of material compatible with and not affected by the concentrate.

4.7.2.4 Piping in constant contact with foam concentrate shall not have a detrimental effect on the foam concentrate.

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

(1) Black steel or unlined cast iron pipe — 100
(2) Galvanized steel pipe — 120
(3) Asbestos-cement or cement-lined cast iron pipe — 140

4.7.3 Fittings.

4.7.3.1 All pipe fittings shall be in accordance with one of the following:

(1) ANSI B16.1, *Cast Iron Pipe Flanges and Flanged Fittings*
(2) ANSI B16.3, *Malleable Iron Threaded Fittings*
(3) ANSI B16.4, *Gray Iron Threaded Fittings*
(4) ANSI B16.5, *Pipe Flanges and Flanged Fittings*
(5) ANSI B16.9, *Factory-Made Wrought Steel Buttwelding Fittings*
(6) ANSI B16.11, *Forged Fittings, Socket-Welding and Threaded*
(7) ANSI B16.25, *Buttwelding Ends*
(8) ASTM A 234, *Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures*

4.7.3.2 Fittings shall not be less than standard weight.

4.7.3.3 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.

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

4.7.3.5* Galvanized fittings shall be used for normally noncorrosive atmospheres.

4.7.3.6 Fittings carrying foam concentrate shall not be galvanized.

4.7.4 Joining of Pipes and Fittings.

4.7.4.1 Pipe threading shall be in conformance with ANSI B1.20.1, *Pipe Threads*.

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

4.7.4.3* Welding practices shall conform to the requirements of AWS D10.9, *Standard for the Qualification of Welding Procedures and Welders for Piping and Tubing*.

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

4.7.4.3.2 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. The net open area of the strainer shall be at least four times the area of the suction piping. 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 normal operating position by one of the following methods:

(1) Electrical, in accordance with *NFPA 72*®, *National Fire Alarm Code*®
(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, an adequate and reliable source of energy shall be used.

4.9.2.4 The need for an alternate power supply shall be determined by the authority having jurisdiction.

4.9.2.5* 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.

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

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 In some cases, it shall be permitted to arrange the system to shut off automatically after a predetermined operating time.

4.9.2.7.1 Automatic shutdown shall be subject to the approval of the authority having jurisdiction.

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

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

4.9.2.8.1 Detection systems 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 place removed from the hazard zone to permit them to be operated safely in an emergency, yet close enough to ensure operator knowledge of fire conditions.

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 System Design

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

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

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

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

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 considered 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* In determining actual solution flow requirements, consideration shall be given to potential foam losses from wind and other factors.

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 can be permitted.

5.2.5 Design Criteria 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, and each outlet shall be sized to deliver foam at approximately the same rate.

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 They 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.

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 (min)
	L/min·m²	gpm/ft²	
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.

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 5.2.5.2.1 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

5.2.5.2.2* Minimum Discharge Times and Application Rates. When fixed foam discharge outlets are used for fixed-roof (cone) tanks containing hydrocarbons, the minimum discharge times and application rates shall be in accordance with Table 5.2.5.2.2.

5.2.5.2.2.1 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.

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 Subsurface Application Design Criteria.

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

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

Hydrocarbon Type	Minimum Application Rate L/min·m²	Minimum Application Rate gpm/ft²	Minimum Discharge Time (min) Type I Foam Discharge Outlet	Minimum Discharge Time (min) Type II Foam Discharge Outlet
Flash point between 37.8°C and 60°C (100°F and 140°F)	4.1	0.10	20	30
Flash point below 37.8°C (100°F) or liquids heated above their flash points	4.1	0.10	30	55
Crude petroleum	4.1	0.10	30	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. The manufacturer shall 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.
(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.

Table 5.2.5.3.4 Minimum Application Rate and Discharge Times for Fixed-Roof (Cone) Tanks Containing Flammable and Combustible Liquids Requiring Alcohol-Resistant Foams

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

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

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.

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 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 approximately the same rate.

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.

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 Plus 1 outlet for each additional 465 m^2 (5000 ft^2)	3 Plus 1 outlet for each additional 697 m^2 (7500 ft^2)

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

5.2.6.3.2 This 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.

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.

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

5.3* Outdoor Open-Top Floating Roof Tanks. *[See Figure 5.3(a) through Figure 5.3(d).]*

5.3.1 Tanks equipped with the following floating roof types are not 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 can be easily submerged if damaged
(5) Pan roofs

5.3.2 Systems for tanks so equipped shall be designed in accordance with 5.4.2.1.

5.3.3* Types of Fires Anticipated.

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

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, there shall be provisions for supplementary protection 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.

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

Hydrocarbon Type	Minimum Discharge Time (min)	Minimum Application Rate	
		L/min·m²	gpm/ft²
Flash point between 37.8°C and 60°C (100°F and 140°F)	30	4.1	0.1
Flash point below 37.8°C (100°F) or liquids heated above their flash points	55	4.1	0.1
Crude petroleum	55	4.1	0.1

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.

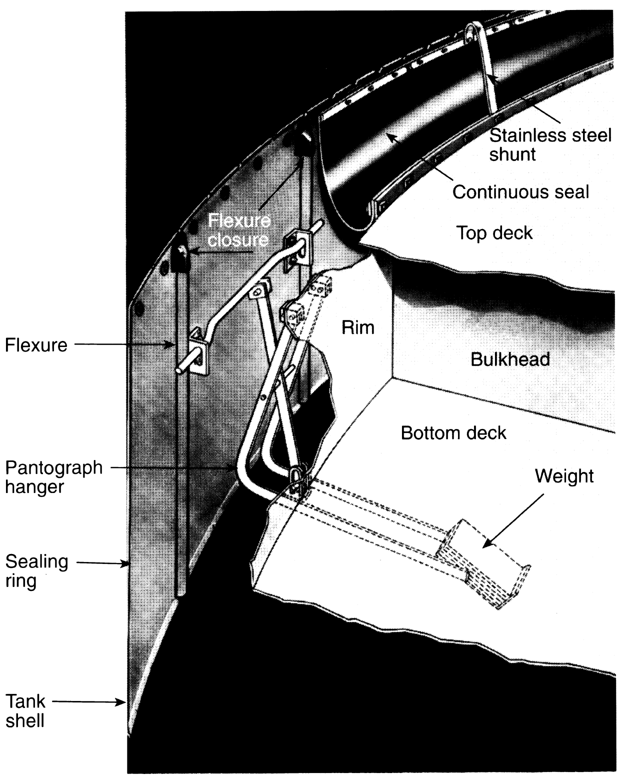

FIGURE 5.3(a) Pantograph-type Seal Open-Top Floating Roof Tank.

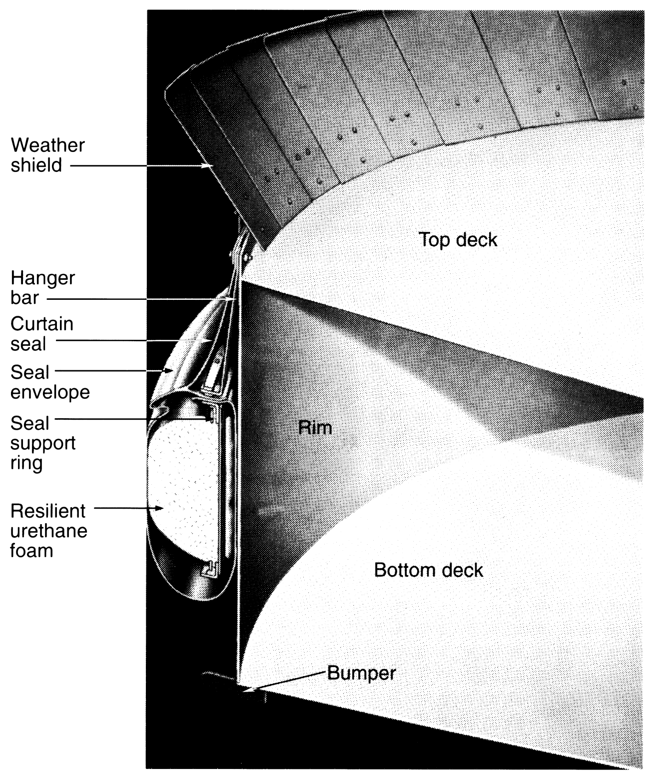

FIGURE 5.3(b) Tube Seal Open-Top Floating Roof Tank.

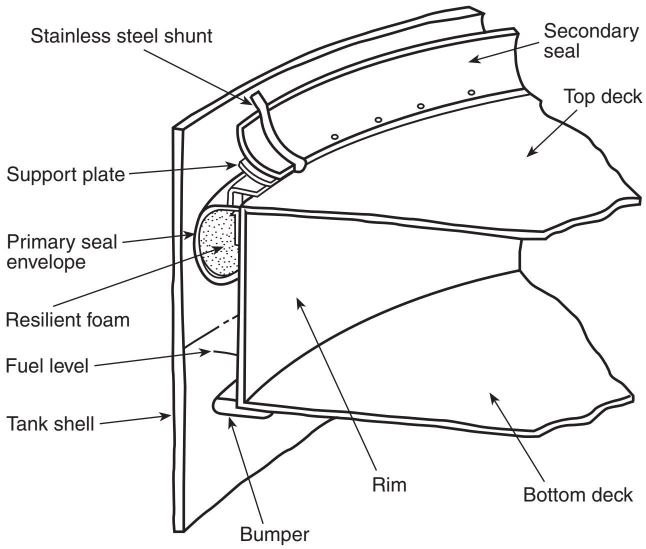

FIGURE 5.3(c) Double Seal System for Floating Roofs.

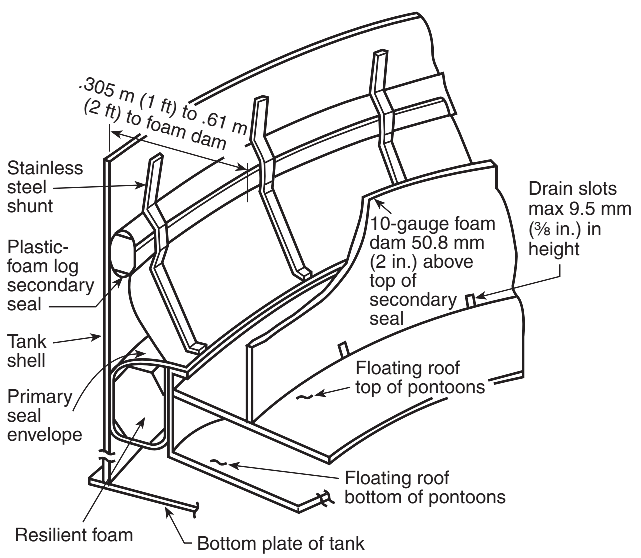

FIGURE 5.3(d) Double Seal System for Floating Roofs Using a Plastic-Foam Log (Secondary Seal).

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.
(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 There shall be two acceptable arrangements when utilizing 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. *(See Figure 5.3.5.3.1.)*

5.3.5.3.2 The requirements specified in the table 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 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.

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.

Table 5.3.5.3.1 Top-of-Seal Fixed Foam Discharge Protection for Open-Top Floating Roof Tanks *(See Figure 5.3.5.3.1)*

Seal Type	Applicable Illustration Detail	Minimum Application Rate		Minimum Discharge Time (min)	Maximum Spacing Between Discharge Outlets with 305-mm (12-in.) Foam Dam		Maximum Spacing Between Discharge Outlets with 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.

5.3.5.4.2 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 278 mm^2 of slot area per m^2 of dammed area (of 0.04 in.^{2} of slot area per ft^2 of dammed area) restricting drain slots to a maximum 9.5 mm (3⁄8 in.) in height as shown in Figure 5.3.5.4.5.

5.3.5.4.5.1 Excessive dam openings for drainage shall be avoided to prevent loss of foam through the drainage slots.

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 wind girder 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 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
(4) Roofs that rely on flotation device closures that can be easily submerged if damaged
(5) Pan roofs

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

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

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

5.4.2.1 Design for Full Surface Fire.

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

5.4.2.1.2 For a full surface fire, the foam facilities shall be designed in accordance with 5.2.3 and Section 5.9, except that separately valved laterals for each foam discharge shall not be required.

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

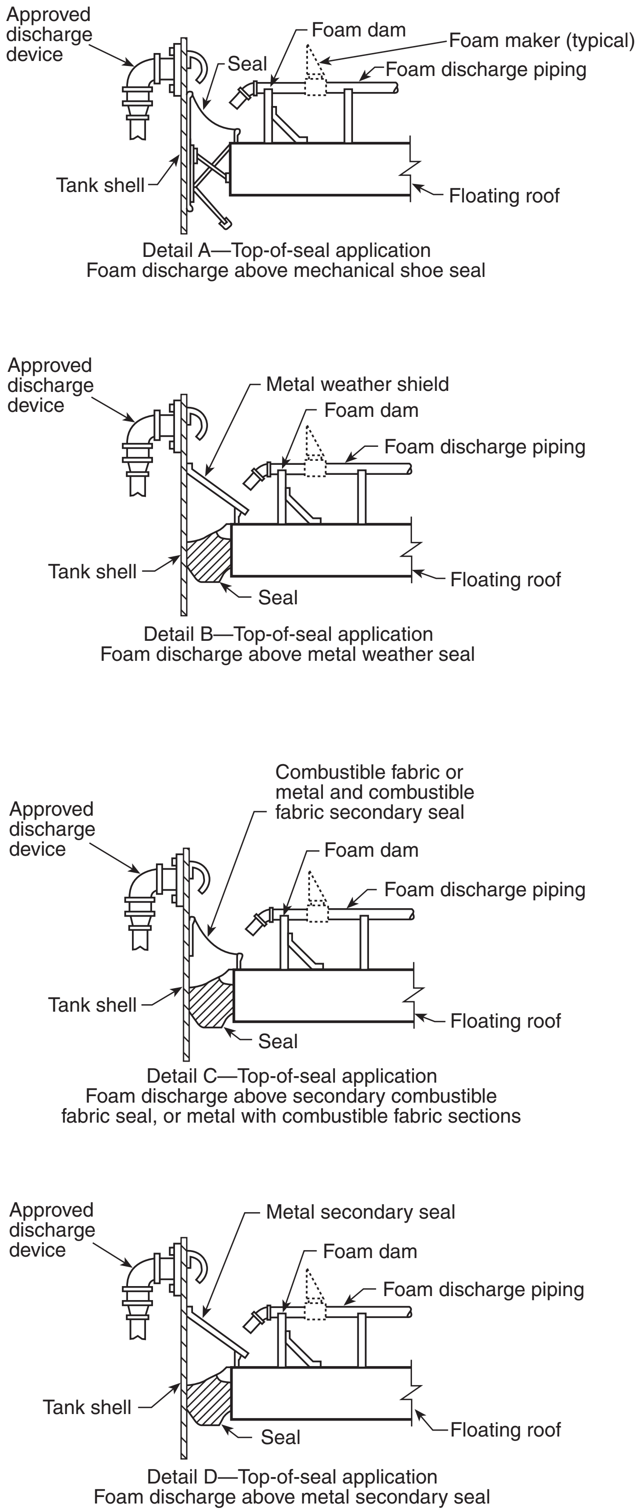

FIGURE 5.3.5.3.1 Typical Foam System Illustrations for Top-of-Seal Fire Protection. Note: Both fixed foam (wall-mounted) and roof-mounted discharge outlets are shown for illustrative purposes. Although both methods are shown, only one is needed.

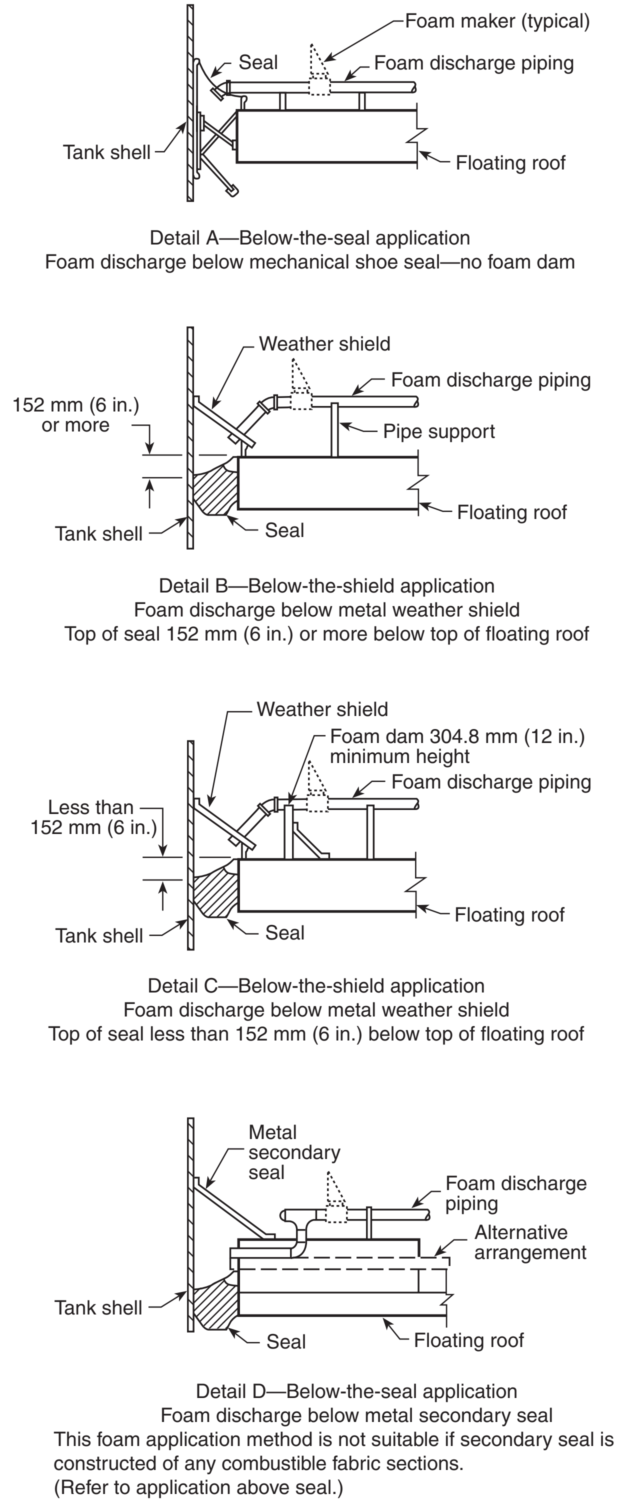

FIGURE 5.3.5.3.5.1 Typical Foam System Arrangement Illustrations for Below-the-Seal (or Shield) Application.

Table 5.3.5.3.6.1 Below-the-Seal Fixed Foam Discharge Protection for Open-Top Floating Roof Tanks *(See Figure 5.3.5.3.5.1.)*

Seal Type	Applicable Illustration Detail	Minimum Application Rate L/min·m²	Minimum Application Rate gpm/ft²	Minimum Discharge Time (min)	Maximum Spacing Between Discharge (Outlets)
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.

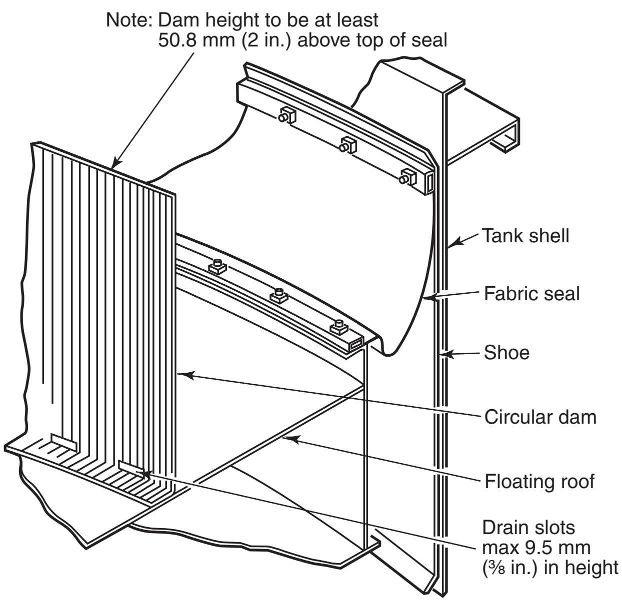

FIGURE 5.3.5.4.5 Typical Foam Dam for Floating Roof Tank Protection.

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

5.4.2.2 Design for Seal Area Fire.

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

5.4.2.2.2 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.

5.4.2.2.3 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.

5.4.2.2.4* Basis of Design.

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

5.4.2.2.4.2 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 m^2 (400 ft^2) 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 · m^2 (0.16 gpm/ft^2) of liquid surface area.

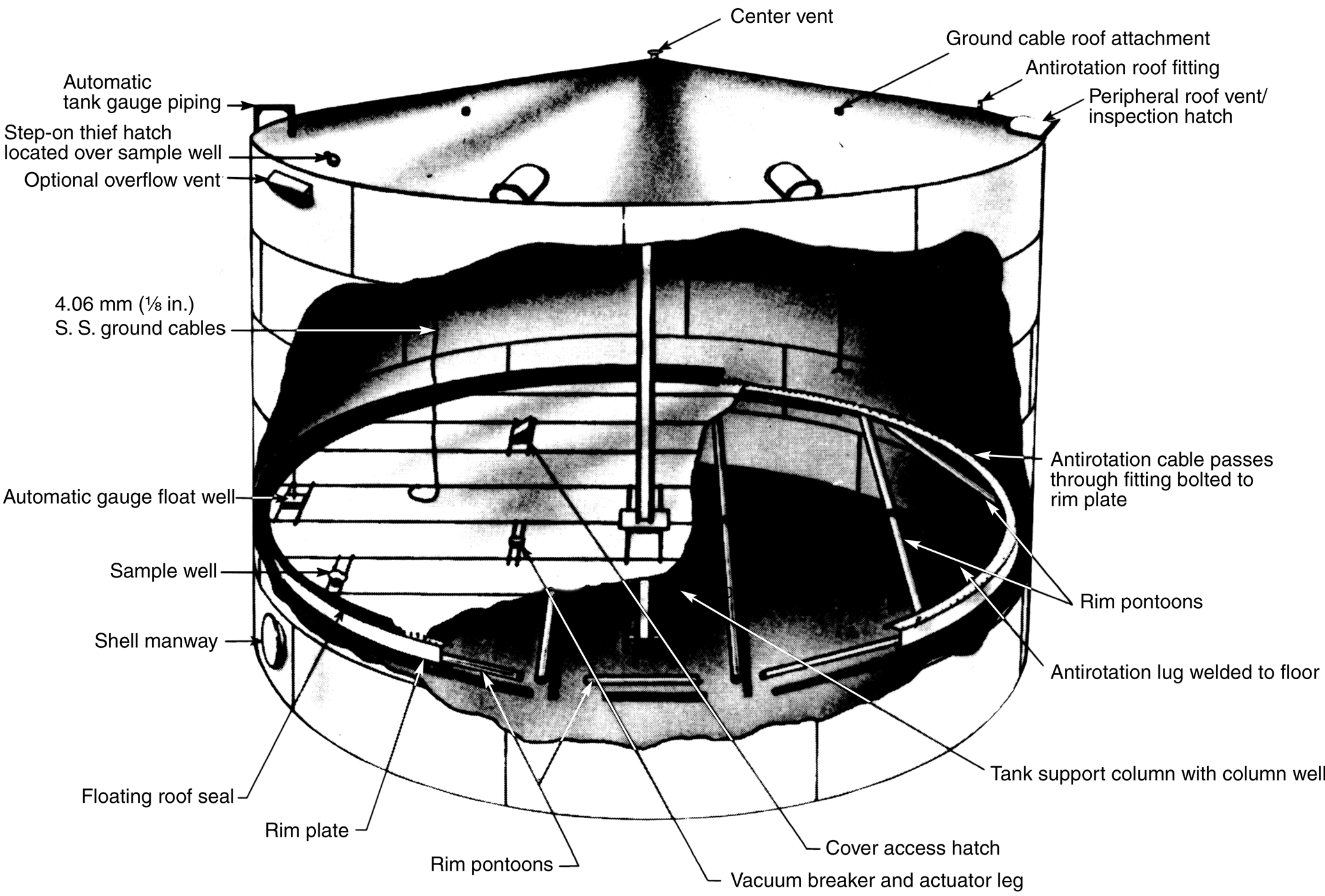

FIGURE 5.4 Typical Covered Floating Roof Tank.

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 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 considered when designing a loading rack foam system.

5.6.3 Methods of Protection. The following shall be permitted to be two acceptable 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, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems.*

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. Minimum foam application rates and discharge times for loading racks protected by monitor nozzles shall be as specified in Table 5.6.5.3.

Table 5.6.5.3 Minimum Application Rates and Discharge Times for Loading Racks Protected by Foam Monitor Nozzle Systems

Foam Type	Minimum Application Rate L/min·m²	Minimum Application Rate gpm/ft²	Minimum Discharge Time (min)	Product Being Loaded
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

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

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

5.7.3.1 Minimum Application Rates and Discharge Times for Fixed Discharge Outlets on Diked Areas Involving Liquid Hydrocarbons. The minimum application rates and discharge times for fixed foam application on diked areas shall be as specified in Table 5.7.3.1.

5.7.3.2* Fixed Foam Discharge Outlets.

5.7.3.2.1 Fixed foam discharge outlets shall be sized and located to apply foam uniformly over the dike area at the application rate specified in Table 5.7.3.1.

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

5.7.3.3 Fixed Foam-Water Sprinklers or Nozzles.

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

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

5.7.3.4 Fixed Low-Level Foam Discharge Outlets.

5.7.3.4.1 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.

5.7.3.4.2 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.

5.7.3.4.3* Limitations.

5.7.3.4.3.1 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.

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

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

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

5.7.3.4.4.2 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.

Table 5.7.3.1 Minimum Application Rates and Discharge Times for Fixed Foam Application on Diked Areas Involving Hydrocarbon Liquids

Type of Foam Discharge Outlets	Minimum Application Rate		Minimum Discharge Time (min)	
	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

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

Foam Type	Minimum Application Rate		Minimum Discharge Time (min)	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

5.7.4.2 Systems using these foams shall require special engineering consideration.

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

(1) Methods of fixed protection shall be the same as those described in 5.7.3.2 for hydrocarbon hazards.
(2) Application rates shall be in accordance with manufacturer recommendations based on listings or approvals for specific products and corresponding foam-making devices.
(3) The minimum discharge time shall be 30 minutes.

5.8* Nondiked Spill Areas. For the purpose of this standard, nondiked spill areas shall be areas where a flammable or combustible liquid spill might occur, uncontained by curbing, dike walls, or walls of a room or building.

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, it is necessary to estimate the potential spill area.

5.8.1.2 Once this 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. In addition to the primary means of protection, some types of hazards shall require provisions for supplemental means of protection. The supplemental protection requirements are described in this section.

5.9.1 Supplemental Foam Hose Stream Requirements.

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

5.9.1.2 The minimum number of fixed or portable hose streams required shall be as specified in Table 5.9.1.2 and shall be available to provide protection of the area.

Table 5.9.1.2 Supplemental Foam Hose Stream Requirements

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

5.9.1.3 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 5.9.1.2.

5.9.1.4 Additional foam-producing materials shall be provided to allow operation of the hose stream equipment simultaneously with tank foam installations as specified in Table 5.9.1.4.

Table 5.9.1.4 Hose Stream Operating Times, Supplementing Tank Foam Installations

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

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

Chapter 6 Specifications and Plans

6.1* Approval of Plans. Plans shall be submitted to the authority having jurisdiction for approval before installation.

6.2 Specifications. Specifications for foam systems shall be developed and shall include the following:

(1) The specifications shall designate the authority having jurisdiction and shall indicate whether submission of plans is required.
(2) The specifications shall state that the installation shall conform to this standard and shall meet the approval of the authority having jurisdiction.
(3) The specifications shall include the specific tests that might be required to meet the approval of the authority having jurisdiction and shall indicate how testing costs are to be met.

6.3 Plans.

6.3.1 Preparation of plans shall be entrusted only to fully experienced and responsible persons.

6.3.2 Plans shall be submitted for approval to the authority having jurisdiction before foam systems are installed or existing systems are modified.

6.3.3 These plans shall be drawn to an indicated scale or shall be dimensioned.

6.3.4 The plans shall include or be accompanied by the following information, where applicable:

(1) Physical details of the hazard, including the location, arrangement, and hazardous materials involved
(2) Type and percentage of foam concentrate
(3) Required solution application rate
(4) Water requirements
(5) Calculations specifying required amount of concentrate
(6)*Hydraulic calculations
(7) Identification and capacity of all equipment and devices
(8) Location of piping, detection devices, operating devices, generators, discharge outlets, and auxiliary equipment
(9) Schematic wiring diagram
(10) Explanation of any special features

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

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

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

Chapter 7 Installation Requirements

7.1 Foam Concentrate Pumps.

7.1.1 Foam Concentrate Pump Discharge. Foam concentrate pump discharge pressure shall not exceed the working pressure of the concentrate piping or components in the system.

7.1.2 Positive displacement pumps and centrifugal pumps capable of overpressuring the system shall be provided with adequate means of pressure relief from the discharge to the supply side of the circuit to prevent excessive pressure and temperature.

7.2 Flushing.

7.2.1 Pumps shall have adequate means for flushing with water.

7.2.2 Foam concentrate piping systems shall be provided with flush inlet and outlet connections.

7.3 Power Supply.

7.3.1 Power supply for the drivers of foam concentrate pumps shall be installed in accordance with NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, and NFPA 70, *National Electrical Code®*.

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

7.3.3 Controller.

7.3.3.1 A controller governing the start-up of concentrate pumps with electric drivers of 30 horsepower or less shall be listed as limited service controller.

7.3.3.2 A controller governing the start-up of foam concentrate pumps with electric drivers of greater than 30 horsepower shall be listed as fire pump controller.

7.3.3.3 A controller governing the start-up of foam concentrate pumps with diesel engine drivers shall be listed as diesel engine fire pump controller.

7.3.4* Service Disconnecting Means.

7.3.4.1 A service disconnecting means in the feeder circuits to limited service controllers shall be permitted, where allowed by the authority having jurisdiction, provided the disconnecting means is supervised for the proper position.

7.3.4.2 Supervision for proper position shall be performed by one of the following:

(1) Central station, proprietary, or remote station signaling electrical supervision service
(2) Local electrical supervision through use of a signaling service that will cause the sounding of an audible signal at a constantly attended point
(3) Locking the disconnect in the correct position with monthly recorded inspections

7.4 Piping.

7.4.1 General Requirements.

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

7.4.1.2 Piping that is subject to freezing shall be installed for proper drainage with a pitch of 4 mm/m (½ in. for every 10 ft) or shall be protected from freezing temperatures.

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

(1) Piping less than 100 mm (4 in.) in diameter.
  (a) Where piping is buried, a swing joint or other means shall be provided at each tank riser to absorb the upward force. The swing joint shall consist of approved standard weight steel, ductile, or malleable iron fittings.
  (b) Where piping is supported aboveground, it shall not be secured for a distance of 15 m (50 ft) from the tank shell to provide flexibility in an upward direction so that a swing joint is not needed. If there are threaded connections within this distance, they shall be back welded for strength.

(2)*The vertical piping of 100 mm (4 in.) in diameter and greater on the protected tank shall be provided with one brace at each shell course.

This design can be used in lieu of swing joints or other approved aboveground flexibility, as specified in 7.4.1.3(1)(a) and 7.4.1.3(2)(b).

7.4.1.4* One flange or union joint shall be provided in each riser at a convenient location, preferably directly below the foam maker, to permit hydrostatic testing of the piping system up to this joint.

7.4.1.5 In systems with semifixed equipment on fixed-roof tanks, the foam or solution laterals to each foam maker shall terminate in connections that are located at a safe distance from the tanks.

7.4.1.6 These connections shall not be located within the dike.

7.4.1.7 Connections shall be located at a distance of at least one tank diameter from the tank but in no case less than 15 m (50 ft).

7.4.1.8 The inlets to the piping shall be fitted with corrosion-resistant metal connections, compatible with the equipment supplying foam solution to the system, and provided with plugs or caps.

7.5 Valves in Systems.

7.5.1 The laterals to each foam discharge outlet on fixed-roof tanks shall be separately valved outside the dike in fixed installations.

7.5.2 Shutoff valves to divert the foam or solutions to the proper tank shall be located either in the central foam station or at points where laterals to the protected tanks branch from the main feed line.

7.5.3 These valves shall not be located within the dike.

7.5.4 Valves shall be located at a distance of at least one tank diameter from the tank but in no case less than 15 m (50 ft).

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

7.5.5 Where two or more foam proportioners are installed in parallel and discharge into the same outlet header, valves shall be provided between the outlet of each device and the header.

7.5.5.1 The water line to each proportioner inlet shall be separately valved.

7.5.6 For subsurface applications, each foam delivery line shall be provided with a valve and a check valve unless the latter is an integral part of the high back-pressure foam maker or pressure generator to be connected at the time of use.

7.5.6.1 Where product lines are used for foam, product valving shall be arranged to ensure foam enters only the tank to be protected.

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

7.6 Hangers, Supports, and Protection for Pipework.

7.6.1 Where protecting hazards where there is a possibility of explosion, pipework shall be routed to afford the best protection against damage.

7.6.2 The supply piping to foam outlets that protect a given hazard in a fire area shall not pass over another hazard in the same fire area.

7.6.3 All hangers shall be of approved types.

7.6.4 Tapping or drilling of load-bearing structural members shall not be permitted where unacceptable weakening of the structure would occur.

7.6.5 Attachments can be made to existing steel or concrete structures and equipment supports.

7.6.6 Where systems are of such a design that the standard method of supporting pipe for protection purposes cannot be used, the piping shall be supported in such a manner as to produce the strength equivalent to that afforded by the standard means of support.

7.7 Hose Requirements. Unlined fabric hose shall not be used with foam equipment.

Chapter 8 Medium- and High-Expansion Systems

8.1 General Information and Requirements. The information and requirements in this chapter shall be generally common to all medium- and high-expansion foam systems.

8.2* Mechanisms of Extinguishment. Medium- and high-expansion foam extinguishes fire by reducing the concentration of oxygen at the seat of the fire, by cooling, by halting convection and radiation, by excluding additional air, and by retarding flammable vapor release.

8.3 Use and Limitations.

8.3.1 While medium- and high-expansion foams are finding application for a broad range of fire-fighting problems, each type of hazard shall be specifically evaluated to verify the applicability of medium- or high-expansion foam as a fire control agent.

8.3.2* Some important types of 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)

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

8.3.4 Medium- and high-expansion foam systems shall not be used on fires in the following hazards unless competent evaluation, including tests, indicates acceptability:

(1) Chemicals, such as cellulose nitrate, that release sufficient 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

8.4 Types of Systems. The types of systems recognized in this standard shall include the following:

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

8.5 Systems Protecting One or More Hazards.

8.5.1 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 except as provided in 8.5.2.

8.5.2 Where, in the opinion of the authority having jurisdiction, 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.

8.6* Personnel Safety.

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

8.6.1.1* To reenter 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.

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

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

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

8.6.2* Electrical Clearances.

8.6.2.1 All system components shall be located to maintain minimum clearances from live parts as shown in Table 8.6.2.1.

8.6.2.2 The clearances given are for altitudes of 1000 m (3300 ft) or less.

Table 8.6.2.1 Clearance from Medium- and High-Expansion Foam Equipment to Live Uninsulated Electrical Components

Nominal Line Voltage (kV)	Nominal Voltage to Ground (kV)	Design BIL[1] (kV)	Minimum Clearance[2] mm	Minimum Clearance[2] 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

[1]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.
[2]For voltages up to 69 kV, the clearances are taken from NFPA 70, *National Electrical Code*®.

8.6.2.2.1 At altitudes in excess of 1000 m (3300 ft), the clearance shall be increased at the rate of 1 percent for each 100 m (330 ft) increase in altitude above 1000 m (3300 ft). The clearances are based on minimum general practices related to design basic insulation level (BIL) values.

8.6.2.2.2 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.

8.6.2.2.3 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 so that the required clearances to ground shall be based on the design BIL used rather than on the nominal line or ground voltage.

8.6.2.2.4 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.

8.7 Operation and Control of Systems.

8.7.1 Methods of Actuation.

8.7.1.1 Systems shall be classified as manual or automatic in accordance with the method of actuation.

8.7.1.2 An automatic system shall be actuated by automatic detection equipment.

8.7.1.3 Such systems also shall have means for manual actuation.

8.7.2* Detection of Fires.

8.7.2.1 Automatic detection shall be used for fixed systems.

8.7.2.1.1 Automatic detection shall be permitted to be omitted only when approved by the authority having jurisdiction.

8.7.2.2* Automatic detection shall be by listed or approved methods or devices capable of detecting and indicating heat, smoke, flame, combustible vapors, or any abnormal condition in the hazard, such as process trouble, likely to produce fire.

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

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

8.7.2.3.2 When the power supply for detection systems is not independent of the supply for the protected area, an emergency, battery-powered supply with automatic switchover shall be provided if the primary supply fails.

8.7.3 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.

8.7.4 Alarms.

8.7.4.1 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.

8.7.4.2 Such devices shall be of such a type and shall be provided in such numbers and at such locations as are necessary to accomplish satisfactorily their purpose, subject to approval of the authority having jurisdiction.

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

8.7.4.4 Alarms shall be provided to give ample warning of discharge where hazards(s) to personnel might exist.

8.7.4.5 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.

8.7.5* Operating Devices.

8.7.5.1 Operating devices shall include foam generators, valves, proportioners, eductors, discharge controls, and shutdown equipment.

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

8.7.5.1.2 A reliable source of energy shall be used.

8.7.5.1.3 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, *Standard for the Installation of Stationary Pumps for Fire Protection.*

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

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

8.7.5.3 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.

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

8.7.5.4.1 Remote control stations for manual actuation might be required where the area is large, egress difficult, or where required by the authority having jurisdiction.

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

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

8.7.5.5.1 If the means for manual actuation of the system required in 8.7.1 provide approved positive operation independent of the automatic actuation, it shall be permitted to be used as the emergency means.

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

8.7.5.5.3 If possible, the system shall be designed so that complete emergency actuation can be accomplished from one location.

8.7.5.6 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.

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

8.8 Water, Foam Concentrate, and Air Supply.

8.8.1 Water Quantity. Water shall be available in sufficient quantity and pressure to supply the maximum number of medium- and high-expansion foam generators likely to operate simultaneously in addition to the demands of other fire protection equipment.

8.8.2 Water Quality.

8.8.2.1* Consideration shall be given to the suitability of the water for production of medium- and high-expansion foam.

8.8.2.2 The manufacturer of the foam concentrate shall be consulted.

8.8.3 Water Storage. Water supply shall be protected against freezing.

8.8.4 Foam Concentrate Quantity. The amount of foam concentrate in the system shall be at least sufficient for the largest single hazard protected or a group of hazards that are to be protected simultaneously.

8.8.5 Foam Concentrate Quality. See Annex G.

8.8.5.1 The foam concentrate used in the system shall be that listed for use with the equipment or a foam concentrate of equivalent quality acceptable to the authority having jurisdiction.

8.8.5.2 The performance of the system shall be dependent on the composition of the foam concentrate as well as other factors.

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

8.8.6 Reserve Supply of Foam Concentrate.

8.8.6.1 There shall be a reserve supply of foam-producing materials to meet design requirements in order to put the system back into service after operation.

8.8.6.2 This supply shall be permitted to be in separate tanks or compartments, in drums or cans on the premises, or available from an approved outside source within 24 hours.

8.8.7 Foam Concentrate Storage.

8.8.7.1 In-service and reserve supplies of foam concentrate shall be stored where the temperature is maintained between 2°C (35°F) and 38°C (100°F) or within such other temperature range for which the concentrate has been listed.

8.8.7.2 The reserve supply containers shall be kept closed tightly in a clean, dry area to prevent contamination or deterioration.

8.8.8* Foam Concentrate Storage Tank.

8.8.8.1 The tank shall be of corrosion-resistant materials and construction compatible with the foam concentrate.

8.8.8.2 Consideration shall be given to design of the storage tank to minimize evaporation of concentrate.

8.8.8.3 The foam equipment manufacturer shall be consulted.

8.9 Air Supply.

8.9.1 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.

8.9.2 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 8.13.5 if test fire indicates that need.

8.9.3 Vents shall be located to avoid recirculation of combustion products into the air inlets of the foam generators.

8.10 Foam-Generating Apparatus Location.

8.10.1 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.

8.10.2* Protection Against Exposure.

8.10.2.1 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.

8.10.2.2 Foam generators installed inside the hazard area shall be constructed to resist or be protected against fire exposure.

8.10.2.3 Such protection shall be permitted to be in the form of insulation, fire-retardant paint, water spray or sprinklers, and so forth. In certain applications, additional generators shall be permitted to be substituted for fire exposure protection with the approval of the authority having jurisdiction.

8.11 Distribution Systems.

8.11.1 Piping and Fittings.

8.11.1.1* The piping and fittings in continuous contact with foam concentrate shall be of corrosion-resistant materials compatible with the foam concentrate used.

8.11.1.2 The remainder of the piping and fittings shall be standard weight (Schedule 40) black or galvanized steel pipe and standard weight black or galvanized steel, ductile, or malleable iron fittings.

8.11.1.3 Consideration shall be given to possible galvanic effects when dissimilar metals are joined, especially in piping that carries foam concentrate.

8.11.2 Arrangement and Installation of Piping and Fittings.

8.11.2.1 Piping shall be installed in accordance with practices outlined in NFPA 13, *Standard for the Installation of Sprinkler Systems.*

8.11.2.2 All piping systems shall be designed using hydraulic calculations to ensure the desired rate of flow at the foam generators.

8.11.2.3 Care shall be taken to avoid possible restrictions due to foreign matter, faulty fabrication, and improper installation.

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

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

8.11.3 Valves.

8.11.3.1 All valves shall be suitable for the intended use, particularly in regard to flow capacity and operation.

8.11.3.1.1 Valves shall be of a listed type or shall be deemed suitable for such use as a part of the system.

8.11.3.2 Valves shall not be easily subject to mechanical, chemical, or other damage.

8.11.4 Ducts.

8.11.4.1 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.

8.11.4.2 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.

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

8.11.4.3 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 authority having jurisdiction.

8.12 Total Flooding Systems General Information.

8.12.1 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.

8.12.2 Uses.

8.12.2.1 This type of system shall be permitted to be used where there is a permanent enclosure around the hazard that is adequate to enable the required amount of fire-extinguishing medium to be built up and to be maintained for the required period of time to ensure the control or extinguishment of the fire in the specific combustible material(s) involved.

8.12.2.2* Examples of hazards that shall be permitted to be successfully protected by total flooding systems include rooms, vaults, storage areas, warehousing facilities, and buildings containing Class A and Class B combustibles either singly or in combination.

8.12.2.3 Fires that shall be permitted to be controlled or extinguished by total flooding methods are divided into the following three categories:

(1) Surface fires involving flammable or combustible liquids and solids
(2) Deep-seated fires involving solids subject to smoldering
(3) Three-dimensioned fires in some flammable liquids

8.12.3 General Requirements.

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

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

8.12.4 Enclosure Specifications.

8.12.4.1 Leakage.

8.12.4.1.1 Since the efficiency of the medium- or high-expansion foam system depends on the development and maintenance of a suitable quantity of foam within the particular enclosure to be protected, leakage of foam from the enclosure shall be avoided.

8.12.4.1.2 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.

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

8.12.4.1.2.2 If any unclosable openings exist, the system shall be designed to compensate for the probable loss of foam and shall be tested to ensure proper performance.

8.12.4.1.3 Ventilation.

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

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

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

8.12.4.1.3.4 Where design criteria demand exhaust fans, they shall be approved for high-temperature operation and installed with due consideration for protection of switches, wiring, and other electrical devices to ensure equal reliability of exhaust fan performance as well as for the foam generators.

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

8.13 Foam Requirements.

8.13.1 General. For adequate protection, medium- or high-expansion foam shall be discharged at a rate sufficient to fill the enclosure to an effective depth above the hazard before an unacceptable degree of damage occurs.

8.13.2 Foam Depth.

8.13.2.1 High-Expansion Foam.

8.13.2.1.1 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.

8.13.2.1.2 For flammable or combustible liquids, the required depth over the hazard shall be permitted to be considerably greater and shall be determined by tests.

8.13.2.2 Medium-Expansion Foam.

8.13.2.2.1 Required depth over the hazard shall vary with expansion.

8.13.2.2.2 Depth shall be determined by tests. *(See Annex G for guidance.)*

8.13.3 Submergence Volume for High-Expansion Foams.

8.13.3.1 Submergence volume shall be defined as the depth as specified in 8.13.2.1.1 multiplied by the floor area of the space to be protected, or, in the case of unsprinklered rooms of internal combustible construction or finish, the entire volume including concealed spaces.

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

8.13.3.3 The volume occupied by stored material shall not be deducted when determining the submergence volume unless approved by the authority having jurisdiction.

8.13.4* Submergence Time for High-Expansion Foams.

8.13.4.1 Recommended times to achieve submergence volume for various types of hazards and building construction shall be as shown in Table 8.13.4.

8.13.4.2 Shorter submergence times might be required depending on the factors included in 8.13.5.

8.13.5* Rate of Discharge.

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

8.13.5.2 High-Expansion Foam.

8.13.5.2.1* The rate of foam discharge necessary for extinguishment or sufficient 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.

Table 8.13.4 Maximum Submergence Time for High-Expansion Foam Measured from Start of Foam Discharge[a] (Minutes)

	Light or Unprotected Steel Construction		Heavy or Protected or Fire-Resistive Construction	
Hazard	**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)[a]	3	2	5	3
Combustible liquids [flash points of 38°C (100°F) and above][b]	4	3	5	3
Low-density combustibles (i.e., foam rubber, foam plastics, rolled tissue, or crepe paper)	4	3[c]	6	4[c]
High-density combustibles (i.e., rolled paper kraft or coated banded)	7	5[c]	8	6[c]
High-density combustibles (i.e., rolled paper kraft or coated unbanded)	5	4[c]	6	5[c]
Rubber tires	7	5[c]	8	6[c]
Combustibles in cartons, bags, or fiber drums	7	5[c]	8	6[c]

[a]This submergence time is based on a maximum of 30 seconds delay between fire detection and start of foam discharge. Any delays in excess of 30 seconds shall be deducted from the submergence times in Table 8.13.4.
[b]Polar solvents are not included in this table. Flammable liquids having boiling points less than 38°C (100°F) might require higher application rates. See NFPA 30, *Flammable and Combustible Liquids Code*. Where use of high-expansion foam is contemplated on these materials, the foam equipment supplier shall substantiate suitability for the intended use.
[c]These submergence times might not be directly applicable to high-piled storage above 4.6 m (15 ft) or where fire spread through combustible contents is very rapid.

8.13.5.2.2 The foam discharge rate shall be sufficient to satisfy the foam depth requirements and submergence times of Table 8.13.4, with compensation for normal foam shrinkage, foam leakage, and breakdown effects of sprinkler discharge.

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

$$R = \left(\frac{V}{T} + R_S\right) \times C_N \times C_L$$

where:
R = rate of discharge in m^3/min (ft^3/min)
V = submergence volume in m^3 (ft^3)
T = submergence time in minutes
R_S = rate of foam breakdown by sprinklers in m^3/min (ft^3/min)
C_N = compensation for normal foam shrinkage
C_L = compensation for leakage

(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:

$$R_S = S \times Q$$

where:
S = foam breakdown in $m^3/\text{min} \cdot \text{L/min}$ ($ft^3/\text{min} \cdot \text{gpm}$) of sprinkler discharge. S shall be 0.0748 $m^3/\text{min} \cdot \text{L/min}$ (10 $ft^3/\text{min} \cdot \text{gpm}$)
Q = estimated total discharge from maximum number of sprinklers expected to operate in L/min (gpm)

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

(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 proper evaluation of the structure. This factor cannot be less than 1.0 even for a structure completely tight below the design filling depth. This factor could be as high as 1.2 for a building with all openings normally closed, depending on foam expansion ratio, sprinkler operation, and foam depth.

8.13.6 Quantity.

8.13.6.1 Sufficient 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.

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

8.13.6.3 Reserve supplies shall be provided in accordance with 8.8.7.

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

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

8.14.2 Where only flammable or combustible liquids are involved, this period shall be permitted to be reduced.

8.14.3 Method.

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

8.14.3.2 Arrangements and procedures shall be provided to maintain the submergence volume without waste of foam concentrate that might be needed in case of reignition.

8.15* Overhaul. Overhaul procedures shall be preplanned carefully to avoid loss of control established by the system.

8.16 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.

8.17 Local Application Systems.

8.17.1 General Information.

8.17.1.1 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 the fire or spill.

8.17.1.2* Uses.

8.17.1.2.1 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.

8.17.1.2.2 For multiple-level or three-dimensional fire hazards where total building flooding is impractical, the individual hazard shall be provided with suitable containment facilities acceptable to the authority having jurisdiction.

8.17.2 General Requirements.

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

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

8.18 Hazard Specifications.

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

8.18.2* Location of Hazard.

8.18.2.1 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.

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

8.19 Foam Requirements for Flammable and Combustible Liquids and Solids.

8.19.1 General. Sufficient 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.

8.19.2 Quantity.

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

8.19.2.2 Reserve supplies shall be provided in accordance with 8.8.7.

8.19.3 Arrangement.

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

8.19.3.2 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 sufficient depth to ensure prompt and final extinguishment.

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

8.20.1* General. High-expansion foam has been shown to be effective in controlling LNG spill test fires and in reducing downwind vapor concentration from unignited LNG spill test fires in confined areas up to 111 m^2 (1200 ft^2).

8.20.2* System Design Considerations.

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

8.20.2.2 Since time to initiate actuation is a critical factor in LNG fire control, the analysis shall consider effects of heat exposure on adjacent plant equipment.

8.20.2.3 In many cases, automatic alarms and actuation shall be required for fixed systems.

8.20.3* Foam Discharge Rate per Unit Area.

8.20.3.1 As established by tests the discharge rate per unit area shall be such that a positive and progressive reduction in radiation is attained within the time limitations established in the analysis.

8.20.3.2 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.

8.20.3.3 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.

8.20.4 Quantity.

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

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

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

8.21 Portable Foam-Generating Devices.

8.21.1 General Information.

8.21.1.1 Description.

8.21.1.1.1 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.

8.21.1.1.2 The proportioning equipment can be integral to or separate from the foam generator.

8.21.1.1.3 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.

8.21.1.2 General Requirements.

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

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

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

8.21.3 Location and Spacing.

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

8.21.3.2 Foam concentrate shall be available for immediate use.

8.21.3.3 These devices shall be located such that they are not exposed to the hazard.

8.21.3.4 Those not preconnected to a water or solution supply and their associated equipment shall be located and arranged for immediate transport to all designated hazards.

8.21.4 Foam Requirements.

8.21.4.1 Rate and Duration of Discharge

8.21.4.1.1 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.

8.21.4.1.2 To the extent that the specific hazards can be identified, the applicable requirements of this chapter shall apply.

8.21.4.2 Simultaneous Use of Portable Foam-Generating Devices Where simultaneous use of two or more devices is possible, sufficient supplies of foam concentrate and water shall be available to supply the maximum number of devices that are likely to be used at any one time.

8.21.5 Equipment Specifications.

8.21.5.1 Hose.

8.21.5.1.1 Hose used to connect the generator to the water or solution supplies shall be listed lined hose.

8.21.5.1.2 Unlined fabric hose shall not be used.

8.21.5.1.3 The hose size and length shall be selected with consideration to the hydraulics of the entire system.

8.21.5.1.4 Such hose shall be stored in an arrangement that will permit immediate use and shall be protected against the weather.

8.21.5.2 Electric Power Supply and Connections.

8.21.5.2.1 Power supply and connections needed for operation of the generator shall be adequate to transmit the required power and shall be selected with consideration given to the intended use.

8.21.5.2.2 All power cables shall be sufficiently rugged to withstand abuse in service, shall be impervious to water, and shall contain a ground wire.

8.21.5.2.3 Electrical connectors shall be waterproof.

8.21.6 Training.

8.21.6.1* All personnel likely to use this equipment shall be properly trained in its operation and in the necessary fire-fighting techniques.

Chapter 9 Marine Applications

9.1* General.

9.1.1 This chapter covers design information for the use of low-expansion foam systems that are necessary for marine applications where required by the authority having jurisdiction.

9.1.2 The provisions of Chapters 4, 5, 6, and 7 of this standard shall not be applicable unless specifically referenced.

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

9.1.3.1 Each manufacturer shall maintain a system design manual describing basic acceptable system design arrangements and denoting each of the manufacturers' products within the system.

9.1.4 Foam concentrates shall be approved.

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

9.1.4.2 Four consecutive fire tests shall be completed — two using sea water and two using fresh water.

9.1.4.3* Concentrates intended for use on polar solvent systems shall be approved for hydrocarbons in accordance with 9.1.4.1 and approved for use on polar solvents in accordance with a method equivalent to UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates*.

9.1.5 The foam supply shall be in accordance with 4.3.2.2.

9.1.6 The water supply shall be in accordance with 4.2.1.1, 4.2.1.2, and 4.2.1.3.

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

9.2 Fixed Low-Expansion Foam Systems for Machinery Spaces.

9.2.1* Where installed, systems protecting machinery spaces shall be capable of discharging a sufficient quantity of expanded foam to provide a foam depth of at least 150 mm (6 in.) over the largest area over which oil is likely to spread.

9.2.2 The minimum foam solution application rate shall be 6.5 L/min·m^2 (0.16 gpm/ft^2) for a minimum of 5 minutes.

9.2.3 The system shall be capable of generating foam suitable for extinguishing hydrocarbon fires.

9.2.4 Means shall be provided for effective distribution of the foam through a permanent system of piping and control valves to suitable discharge outlets and for foam to be effectively directed by fixed foam outlets.

9.2.5 The foam expansion ratio shall not exceed 12:1.

9.2.6 Where a deck foam system is also installed, the foam supply and proportioning system shall not be required to be separate.

9.2.7 The quantity of foam concentrate shall be that required to meet the single largest system demand.

9.2.8 Controls.

9.2.8.1 System controls shall be simple to operate, and grouped together in a location accessible during fire conditions in the protected area.

9.2.8.2 Instructions in permanent lettering shall be affixed to the equipment or in a position adjacent thereto.

9.2.8.3 Remotely controlled devices shall have local mechanical override.

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

9.3.1* Purpose. The purpose of this section shall be to provide guidance for the design and arrangement of deck foam systems that are expected to provide the following performance:

(1) Extinguish deck spill fires and maintain a foam blanket while hot metal cools.
(2) Control or suppress cargo manifold fires except those involving three-dimensional pressurized liquid fires.
(3) Suppress or control tank fires involving a portion of the cargo area assuming that the top of the tank(s) within the design area is open to weather and that the trajectory of the foam is not obstructed.
(4) Provide protection for the crew while arrangements are being made to abandon ship.
(5) During lightering operations, the deck foam system flowing water shall protect the exposed vessel from fire on an adjacent ship while preparations are made to get the exposed vessel under way.
(6) The deck foam system is not intended to provide extinguishment, suppression, or control of incidents resulting from major explosions or collisions that cause the fire to exceed the area of the single largest tank.
(7) The deck foam system shall be designed and arranged to withstand the effects of weather, vibration, corrosion, strain, and impact expected during the ship's operation.
(8) Suppress vapors from an unignited spill on deck.

9.3.2 Control Station.

9.3.2.1 The main control station for the system shall be located aft of the cargo area and be operable in the event of fire in the main area protected.

9.3.2.2* Operating instructions and diagrams of piping systems and valves shall be provided in clear and permanent lettering and shall be affixed to the equipment or in a position near thereto.

9.3.2.2.1 The diagrams shall show which valves are to be opened in the event the system must be activated.

9.3.2.2.2 The diagrams shall explain thoroughly and clearly all the steps necessary to put the system into operation.

9.3.2.2.3 Each valve shall be labeled describing its function.

9.3.2.3 The control station shall be provided with emergency lighting.

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

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

(1) *For hydrocarbon fuels.*
   (a) Deck spill calculation. 6.50 L/min·m^2 (0.16 gpm/ft^2) over 10 percent of the cargo block deck area, where the cargo block deck area is the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces
   (b) Largest tank calculation. 9.78 L/min·m^2 (0.24 gpm/ft^2) of the horizontal sectional area of the single largest tank
   (c) Largest monitor calculation. 3.0 L/min·m^2 (0.074 gpm/ft^2) of the area protected by the largest monitor, such area being entirely forward of the monitor, but not less than 1250 L/min (330 gpm)
(2) *For polar solvents.* Since required foam application rates can vary, polar solvents are placed in representative groups based upon fire performance tests. Fire tests are used to determine the minimum foam design application rate for the group and are conducted using one or more solvents representing the most difficult extinguishment case or the actual polar solvent. These minimum foam design application rates and polar solvent groupings shall be specified in the foam manufacturer's system design manual and shall be approved:
   (a) Deck spill calculation. The highest required foam application rate for any polar solvent that can be transported by the ship, applied over 10 percent of the cargo block deck area, where the cargo block deck area is the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces

(b) Most demanding tank calculation. 150 percent of the highest required foam application rate, for any polar solvent that can be transported by the ship, applied over the horizontal sectional area of the single largest tank
(c) Where dedicated cargo tanks are specifically designed for a particular polar solvent and such solvent cannot be carried in other tanks, the foam system design can take into consideration this limitation.
(d) Largest monitor calculation. 45 percent of the highest required foam application rate for any polar solvent that can be transported by the ship, applied over the area protected by the foam monitor, such area being entirely forward of the monitor, but not less than 1250 L/min (330 gpm)

9.3.5 Discharge Duration.

9.3.5.1* Foam concentrate shall be provided to supply the system for 30 minutes.

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

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

9.3.5.3* Minimum discharge duration shall be based on the actual capacity of the installed equipment.

9.4* Foam Outlet Devices.

9.4.1 One hundred percent of the required foam application shall be by using one or two monitors located immediately aft of the protected area.

9.4.2 On tankers less than 4000 metric tons dead weight, hand hoselines only shall be permitted to be installed in lieu of monitors specified in 9.4.1 provided that the capacity of each hand hoseline is at least 25 percent of the total foam solution flow rate.

9.5 Monitors.

9.5.1 The capacity of any monitor shall be at least 3.02 L/min·m^2 (0.074 gpm/ft^2) of the deck area protected by that monitor, with such area being entirely forward of the monitor.

9.5.2 The capacity of each monitor shall be not less than 50 percent of the required foam application rate and not less than 1250 L/min (330 gpm).

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

9.5.4 Foam monitors and hand hoseline connections shall be situated both port and starboard at the front of the accommodation space facing the cargo tank's deck.

9.5.4.1 If provided, these monitors shall be located at least 2.5 m (8.2 ft) above the main deck and shall be directly accessible to the deck above the freeboard deck.

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

9.5.5.1 Ships fitted with bow or stern loading and unloading arrangements shall be provided with one or more additional monitors located to protect the bow or stern arrangements.

9.5.5.2 The area of the cargo line fore or aft of the cargo block area shall be provided with monitor protection.

9.5.5.3 Foam monitors shall be mounted on substantial platforms.

9.5.5.4 Platforms shall permit 360 degree access around the monitors.

9.5.5.5 Platforms shall be raised to allow the monitors an unobstructed throw insofar as practical.

9.5.5.6 The monitor isolation valve shall be accessible from the monitor platform.

9.5.5.7 Platforms higher than 2 m (6.5 ft) shall be provided with hand rails or chain rails.

9.5.5.8 Access to the monitor platform shall be via walkway or permanent ladder.

9.5.5.9 Provisions shall be made for securing monitors while at sea.

9.5.6 Monitors.

9.5.6.1 Monitors over 3785 L/min (1000 gpm) shall be provided with two operator handholds or one handwheel for each swivel.

9.5.6.2 Monitors shall be designed to prevent unwanted movement due to reaction forces.

9.5.6.3 Monitors shall be capable of being locked into position while operating at full flow.

9.6 Hand Hoselines.

9.6.1 Hand hoselines shall be provided to ensure flexibility of action during fire-fighting operations and to cover areas obstructed from monitors.

9.6.2 The capacity of any hand hoseline shall be not less than 401 L/min (106 gpm) and the hand hoseline throw in still air conditions shall be not less than 15 m (50 ft).

9.6.3 The number and location of foam solution outlets shall be such that foam from at least two hand hoselines can be simultaneously directed onto any part of the cargo block deck area.

9.6.4 Hand hoselines and hydrants shall be mounted on monitor platforms or at deck level.

9.7 Hydraulic Calculations.

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

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

9.7.3 Orifices shall be permitted to balance flows to monitors and fixed foam outlets.

9.8 Isolation Valves.

9.8.1 Isolation valves shall be provided in the water, foam concentrate, and foam solution mains (immediately forward of any monitor position) to isolate damaged sections. In addition, each monitor and hose station shall have an isolation valve.

9.8.2 Isolation valves shall be operable from readily accessible locations.

9.8.3 Monitor isolation valves shall be in accordance with 9.5.5.3 through 9.5.5.9.

9.8.4 All isolation valves shall be installed with the bonnet above the horizontal.

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

9.9 Hangers, Supports, and Protection of Pipework.

9.9.1 Pipework shall be routed to afford protection against damage.

9.9.2* All hangers and piping supports shall be designed for marine applications.

9.9.3* Deck foam solution piping shall be independent of fire main piping.

9.9.3.1 Where the fire main and foam main are connected to a common monitor, check valves shall be installed.

9.9.4* The system shall be arranged to prevent the possibility of freezing.

9.9.4.1 Portions of the system exposed to weather shall be self-draining.

9.9.4.2 Wet or pressurized portions of the system shall be protected against freezing.

9.10 Testing and Inspection.

9.10.1* Foam systems shall be inspected and tested in accordance with Chapter 9 and Chapter 10.

9.10.2 Annual testing shall include tests conducted in accordance with Section 10.6.

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

9.11 Foam System Concentrate Storage.

9.11.1 Foam concentrate storage shall be in accordance with 4.3.2.4.

9.11.1.1* The primary deck foam concentrate storage tank shall be located on or above the freeboard deck level in the space containing the system control station described in 9.3.2.

9.11.1.2 All foam concentrate shall be stored in an accessible location unlikely to be cut off in the event of fire or explosion and not having direct opening or exposure to the cargo area.

9.11.2 Foam concentrate tanks shall be in accordance with 4.3.2.3.

9.11.2.1* Tanks shall have expansion domes.

9.11.2.2 Tanks shall be fitted with baffles to prevent sloshing.

9.11.2.3 Each concentrate storage tank shall be provided with a brass, stainless steel, or other corrosion-resistant pressure vacuum (PV) vent.

9.11.2.4 Each tank shall have a substantial support structure suitable for mounting the tank to the ship's structure.

9.11.2.5 Each tank shall have a sump or other means to prevent clogging of the foam concentrate suction pipe in the event of sedimentation or other foreign materials in the tank.

9.11.2.6 The foam concentrate suction pipe shall take suction above the bottom of the sump.

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

9.11.4 Each tank shall have a manway or openings for internal inspection and access.

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

9.11.6 Atmospheric tanks shall be provided with means for continuous refilling of the tank.

9.11.7 Foam concentrate storage shall be within the foam concentrate manufacturer's recommended temperature limitations.

9.11.7.1 Storage spaces shall be provided with heat to prevent freezing of the foam concentrate and piping.

9.11.7.2 Storage shall be in accordance with 4.3.2.4 and 4.3.2.4.1.

9.11.8 Foam concentrate compatibility shall be in accordance with 4.4.1 and 4.4.2. The foam concentrate storage tank shall be provided with a label specifying foam manufacturer, foam type, and quantity.

9.11.9 Only one type of foam concentrate shall be carried on board.

9.12 Supply Arrangements.

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

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

9.12.2* Foam concentrate pumps shall be in accordance with Section 4.6.

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

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

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

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

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

9.13 Piping Materials.

9.13.1 Piping shall be in accordance with Table 9.13.1. Other materials shall be permitted to be used provided they have physical properties and corrosion resistance equivalent to the piping identified in Table 9.13.1 and are approved by the authority having jurisdiction.

Table 9.13.1 Piping Materials

Service	Pipe	Valves	Fittings	Takedown Joints
Seawater or foam solution (up to 225 psi and 350°F)	Carbon steel, seamless or electric resistance weld, standard wall, galvanized[1,2]. ASTM A 53, Type E or S, Gr. A or ASTM A 106, Gr. A Schedule 40 minimum	*Body:* Carbon steel, ASTM A 216 Gr. WCB or ductile iron, ASTM A 395 *Trim:* Bronze or 316 SS *Ends:* Flanged ANSI B16.5 Class 150	*3 in. and larger:* Wrought steel, standard wall, galvanized per ANSI B16.9, 150 lb minimum *2 in. and smaller:* Socket weld steel, 2000#, galvanized per ANSI B16.11 ASTM A 234 Gr. WPB	*3 in. and larger:* Slip-on or buttweld flange *2 in. and smaller:* Socket weld flange ANSI B16.5 Class 150, ASTM A 105
Foam concentrate (in the hazard area)	Carbon steel, seamless or electric resistance weld, standard wall. ASTM A53, Type E or S, Gr. A or ASTM A 106, Gr. A OR Stainless steel, seamless, standard wall pipe ASTM A 312 Gr. TP304L or TP316L	*Body:* Carbon steel, ASTM A 216 Gr. WCB or ASTM A 105 *Trim:* 304L or 316L SS *Ends:* Flanged ANSI B16.5 Class 150 or screwed OR *Body:* Forged stainless steel, ASTM A 182 Gr. F304L or F316L *Trim:* 304L or 316L SS *Ends:* Flanged ANSI B16.5 Class 150 or screwed	Socket weld or threaded carbon steel, 2000# per ANSI B16.11 ASTM A 234 Gr. WPB OR Socket weld or threaded stainless steel, 2000# per ANSI B16.11 ASTM A 182 Gr. F304L or F316L	Screwed or socket weld flange per ANSI B16.5 Class 150 ASTM A 105 or ASTM A 182 Gr. 304L or Gr. 316L OR Screwed or socket weld union, 2000# per ANSI B16.11 ASTM A 105 or ASTM A 182 Gr. 304L or Gr. 316L

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

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

9.13.3 Foam concentrate piping shall be constructed of material compatible with, and not affected by, the concentrate.

9.13.4 Foam concentrate piping shall not be galvanized.

9.13.5* Pipe thread joint sealants used for foam concentrate lines shall be in accordance with the foam concentrate manufacturers' recommendations.

Chapter 10 Testing and Acceptance

10.1 Inspection and Visual Examination.

10.1.1 Foam systems shall be examined visually to determine that they have been properly installed.

10.1.2 Foam systems shall be inspected for such items as conformity with installation plans; continuity of piping; removal of temporary blinds; accessibility of valves, controls, and gauges; and proper installation of vapor seals, where applicable.

10.1.3 Devices shall be checked for proper identification and operating instructions.

10.2 Flushing after Installation.

10.2.1 In order to remove foreign materials that have entered both underground and aboveground water supply mains during installation, the water supply mains shall be flushed thoroughly at the maximum practicable rate of flow before connection is made to system piping.

10.2.2 The minimum rate of flow for flushing shall not be less than the water demand rate of the system, as determined by the system design.

10.2.3 The flow shall be continued for a time to ensure thorough cleaning.

10.2.3.1 Tests shall include a complete check of electrical control circuits and supervisory systems to ensure proper operation and supervision in the event of failure.

10.2.4 Disposal of flushing water shall be arranged.

10.2.5 All foam system piping shall be flushed after installation, using the system's normal water supply with foam-forming materials shut off, unless the hazard cannot be subjected to water flow.

10.2.6 Where flushing cannot be accomplished, pipe interiors shall be carefully visually examined for cleanliness during installation.

10.3* Acceptance Tests.

10.3.1 The completed system shall be tested by qualified personnel to meet the approval of the authority having jurisdiction.

10.3.2 These tests shall be used to determine that the system has been properly installed, and that it functions as intended.

10.4 Pressure Tests.

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

10.4.1.1 All normally dry horizontal piping shall be inspected for drainage pitch.

10.5 Operating Tests.

10.5.1 Before approval, all operating devices and equipment shall be tested for proper function.

10.5.2 Tests for total flooding systems shall establish that all automatic closing devices for doors, windows, and conveyor openings, and automatic equipment interlocks, as well as automatic opening of heat and smoke vents or ventilators, will function upon system operation.

10.5.3 Operating instructions provided by the supplier and proper device identification shall be checked.

10.6* Discharge Tests.

10.6.1 Where conditions permit, flow tests shall be conducted to ensure that the hazard is fully protected in conformance with the design specification.

10.6.2 The following data shall be required as follows:

(1) Static water pressure
(2) Residual water pressure at the control valve and at a remote reference point in the system
(3) Actual discharge rate
(4) Consumption rate of foam-producing material
(5) Concentration of the foam solution
(6) Foam quality (expansion and ¼ drain time) or foam discharge shall be conducted, or the foam discharge shall be visually inspected to ensure that it is satisfactory for the purpose intended.

10.6.3 Foam concentration shall have one of the following proportions:

(1) Not less than the rated concentration
(2)*No more than 30 percent above the rated concentrate, or 1 percentage point above the rated concentration (whichever is less). For information on tests for physical properties of foam, see Annex C.

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

Chapter 11 Maintenance

11.1* Periodic Inspection.

11.1.1 At least annually, all foam systems shall be thoroughly inspected and checked for proper operation.

11.1.2 The inspection shall include performance evaluation of the foam concentrate or premix solution quality or both.

11.1.3 Test results that deviate more than 10 percent from those recorded in acceptance testing shall be discussed immediately with the manufacturer.

11.1.4 The goal of this inspection and testing shall be to ensure that the system is in full operating condition and that it remains in that condition until the next inspection.

11.1.5 The inspection report, with recommendations, shall be filed with the owner.

11.1.6 Between the regular service contract inspections or tests, the system shall be inspected by competent personnel following an approved schedule.

11.2* Foam-Producing Equipment.

11.2.1 Proportioning devices, their accessory equipment, and foam makers shall be inspected.

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

11.3 Piping.

11.3.1 Aboveground piping shall be examined to determine its condition and to verify that proper drainage pitch is maintained.

11.3.2 Pressure tests of normally dry piping shall be made when visual inspection indicates questionable strength due to corrosion or mechanical damage.

11.3.3 Underground piping shall be spot-checked for deterioration at least every 5 years.

11.4 Strainers. Strainers shall be inspected periodically and shall be cleaned after each use and flow test.

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

11.6 Foam Concentrate Inspection.

11.6.1 At least annually, an inspection shall be made of foam concentrates and their tanks or storage containers for evidence of excessive sludging or deterioration.

11.6.2 Samples of concentrates shall be sent to the manufacturer or qualified laboratory for quality condition testing.

11.6.3 Quantity of concentrate in storage shall meet design requirements, and tanks or containers shall normally be kept full, with space allowed for expansion.

11.7 Operating Instructions and Training.

11.7.1 Operating and maintenance instructions and layouts shall be posted at control equipment with a second copy on file.

11.7.2 All persons who are expected to inspect, test, maintain, or operate foam-generating apparatus shall be thoroughly trained and training shall be kept current over time.

Annex A Explanatory Material

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

A.1.1 Fire-fighting foam is an aggregate of air-filled bubbles formed from aqueous solutions and is lower in density than flammable liquids. It is used principally to form a cohesive floating blanket on flammable and combustible liquids and prevents or extinguishes fire by excluding air and cooling the fuel. It also prevents re-ignition by suppressing formation of flammable vapors. It has the property of adhering to surfaces, which provides a degree of exposure protection from adjacent fires.

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

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

Large-spill flammable liquid fires can be fought with mobile equipment, such as an aircraft crash truck or industrial foam truck equipped with agent and equipment capable of generating large volumes of foam at high rates. Foam for this type of hazard can be delivered as a solid stream or in a dispersed pattern. (Standards for industrial foam trucks include NFPA 1901, *Standard for Automotive Fire Apparatus*, and standards for aircraft crash trucks include NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles*.)

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

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

To determine where foam protection is required, see applicable standards such as NFPA 30, *Flammable and Combustible Liquids Code*.

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

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction. The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.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.

A.3.3.4 Eductor (Inductor). *Air Foam Hose Nozzle with Built-in Eductor.* The type of proportioner in which the jet in the foam maker is utilized to draft the concentrate *[see Figure A.3.3.24.3(a)]*. *Limitations.* The bottom of the concentrate container should not be more than 1.8 m (6 ft) below the level of the foam maker. The length and size of hose or pipe between the concentrate container and the foam maker should conform to the recommendations of the manufacturer. *Hydrocarbon Surfactant-Type Foam Concentrates.* These are synthetic foaming agents generally based on a hydrocarbon surface active agent. They produce foams of widely different character (expansion and drainage times), depending on the type of foam-producing devices employed. In general, such foams do not provide the stability and burn-back resistance of protein-type foams or the rapid control and extinguishment of AFFF, but they can be useful for petroleum-product spill fire fighting in accordance with their listings and approvals. There are hydrocarbon-base foaming agents that have been listed as foaming agents, wetting agents, or combination foaming/wetting agents. The appropriate listings should be consulted to determine proper application rates and methods.

A.3.3.13 Foam-Generating Methods. Foam nozzle and monitor streams may also be employed for the primary protection of process units and buildings, subject to the approval of the authority having jurisdiction. The discharge characteristics of the equipment selected to produce foam nozzle and monitor streams for outdoor storage tank protection should be verified by actual tests to make certain that the streams will be effective on the hazards involved. *[See Figure A.3.3.13(a) through Figure A.3.3.13(e).]*

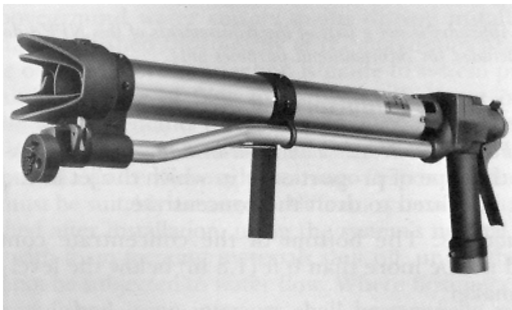

FIGURE A.3.3.13(a) Handline Foam Nozzle.

FIGURE A.3.3.13(b) Adjustable Straight Stream-to-Fan Pattern Foam-Water Monitor.

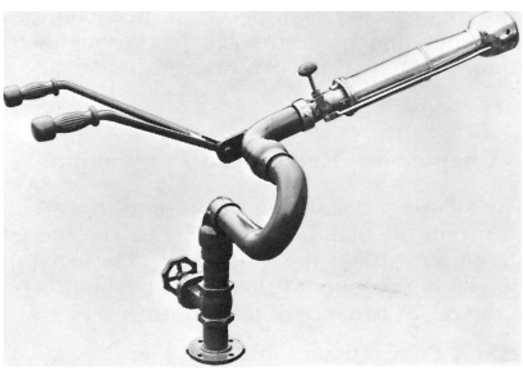

FIGURE A.3.3.13(c) Adjustable Straight Stream-to-Spray Foam-Water Monitor.

A.3.3.24.3 In-Line Eductor. This eductor is for installation in a hoseline, usually at some distance from the foam maker or playpipe, as a means of drafting air foam concentrate from a container. *[See Figure A.3.3.24.3(a) and Figure A.3.3.24.3(b).]*

It has the following limitations:

(1) The in-line eductor must be designed for the flow rate of the particular foam maker or playpipe with which it is to be used. The device is very sensitive to downstream pressures and accordingly is designed for use with specified lengths of hose or pipe located between it and the foam maker.
(2) The pressure drop across the eductor is approximately one-third of the inlet pressure.
(3) The elevation of the bottom of the concentrate container should not be more than 1.8 m (6 ft) below the eductor.

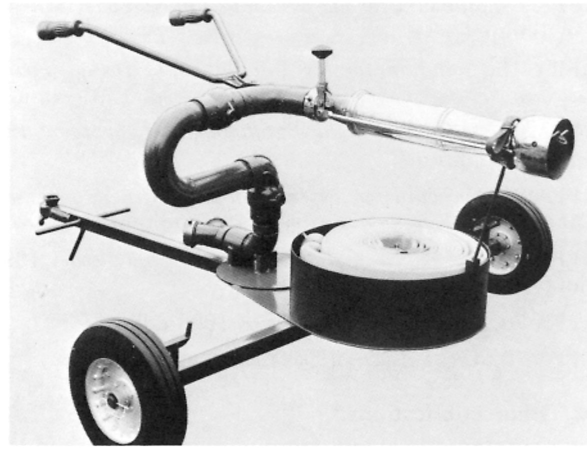

FIGURE A.3.3.13(d) Wheeled Portable Foam-Water Monitor.

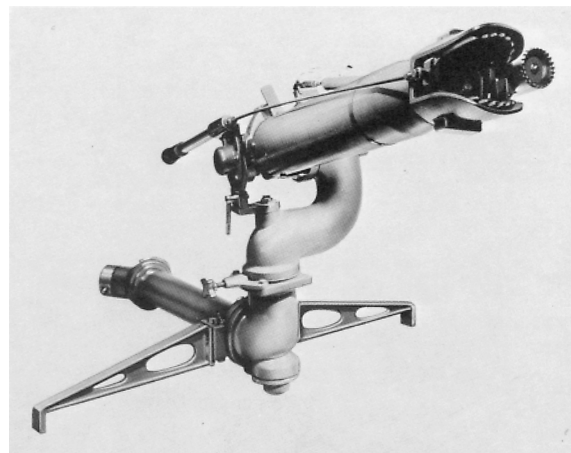

FIGURE A.3.3.13(e) Portable Foam-Water Monitor.

A.3.3.24.4 Metered Proportioning. By means of an auxiliary pump, foam compound is injected into the water stream passing through an inductor. The resulting foam solution is then delivered to a foam maker or playpipe. The proportioner can be inserted into the line at any point between the water source and foam maker or playpipe. *[See Figure A.3.3.24.4(a) and Figure A.3.3.24.4(b).]*

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

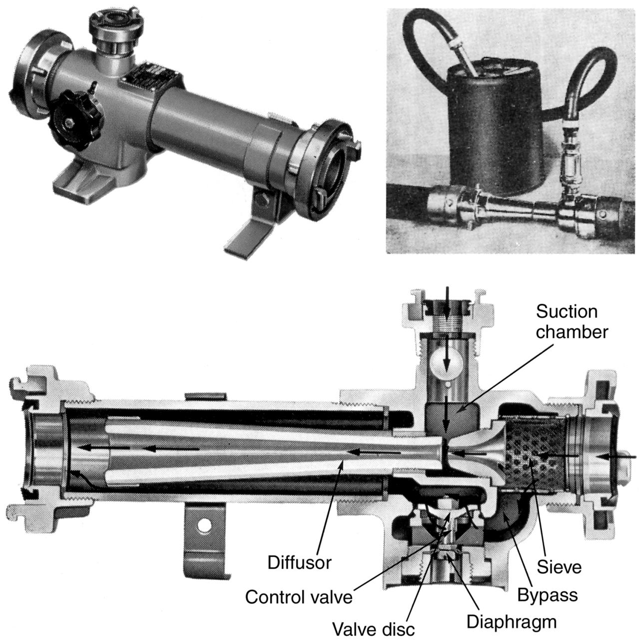

FIGURE A.3.3.24.3(a) In-Line Eductor.

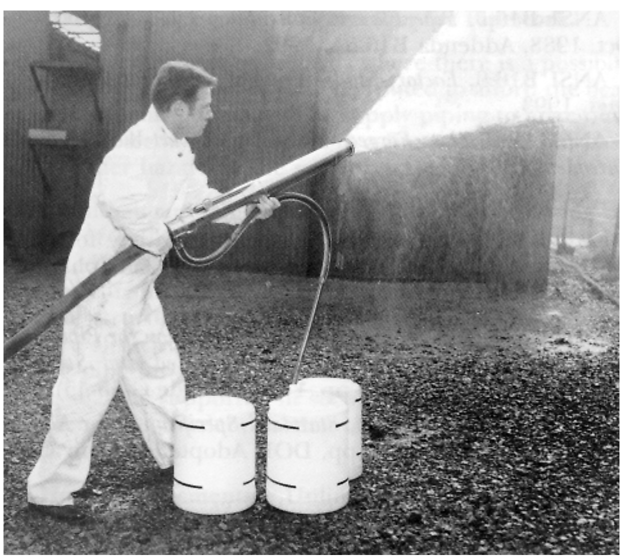

FIGURE A.3.3.24.3(b) Air Foam Hose Nozzle with Built-in Eductor.

Metered proportioning has the following limitations:

(1) The capacity of the proportioner can be varied from approximately 50 percent to 200 percent of its rated capacity.
(2) The pressure drop across the proportioner ranges from 34 kPa to 207 kPa (5 psi to 30 psi), depending on the volume of water flowing through the proportioner within the capacity limits of item (1) above.
(3) A separate pump is needed to deliver concentrate to the proportioner.

A.3.3.24.5 Pressure Proportioning Tank. This method employs water pressure as the source of power. With this device, the water supply pressurizes the foam concentrate storage tank. At the same time, water flowing through an adjacent venturi or orifice creates a pressure differential. The low-pressure area of the venturi is connected to the foam concentrate tank, so that the difference between the water supply pressure and this low-pressure area forces the foam concentrate through a metering orifice and into the venturi. Also, the differential across the venturi varies in proportion to the flow, so one venturi will proportion properly over a wide flow range. The pressure drop through this unit is relatively low. *[See Figure A.3.3.24.5(a).]*

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

The pressure proportioning tank has the following limitations:

(1) Foam concentrates with specific gravities similar to water can create a problem when mixed.
(2) The capacity of these proportioners can be varied from approximately 50 percent to 200 percent of their rated capacity.
(3) The pressure drop across the proportioner ranges from 34 kPa to 207 kPa (5 psi to 30 psi), depending on the volume of water flowing within the capacity limits of item (2) above.
(4) When the concentrate is exhausted, the system must be turned off, and the tank drained of water and refilled with foam concentrate.
(5) Since water enters the tank as the foam concentrate is discharged, the concentrate supply cannot be replenished during operation, as with other methods.
(6) This system proportions at a significantly reduced percentage at low flow rates and should not be used below minimum design flow rate.

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

Diaphragm pressure proportioning tanks operate through a similar range of water flows and according to the same principles as pressure proportioning tanks. The added design feature is a reinforced elastomeric diaphragm (bladder) that can be used with all concentrates listed for use with that particular diaphragm (bladder) material. *[See Figure A.3.3.24.5(b).]*

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

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

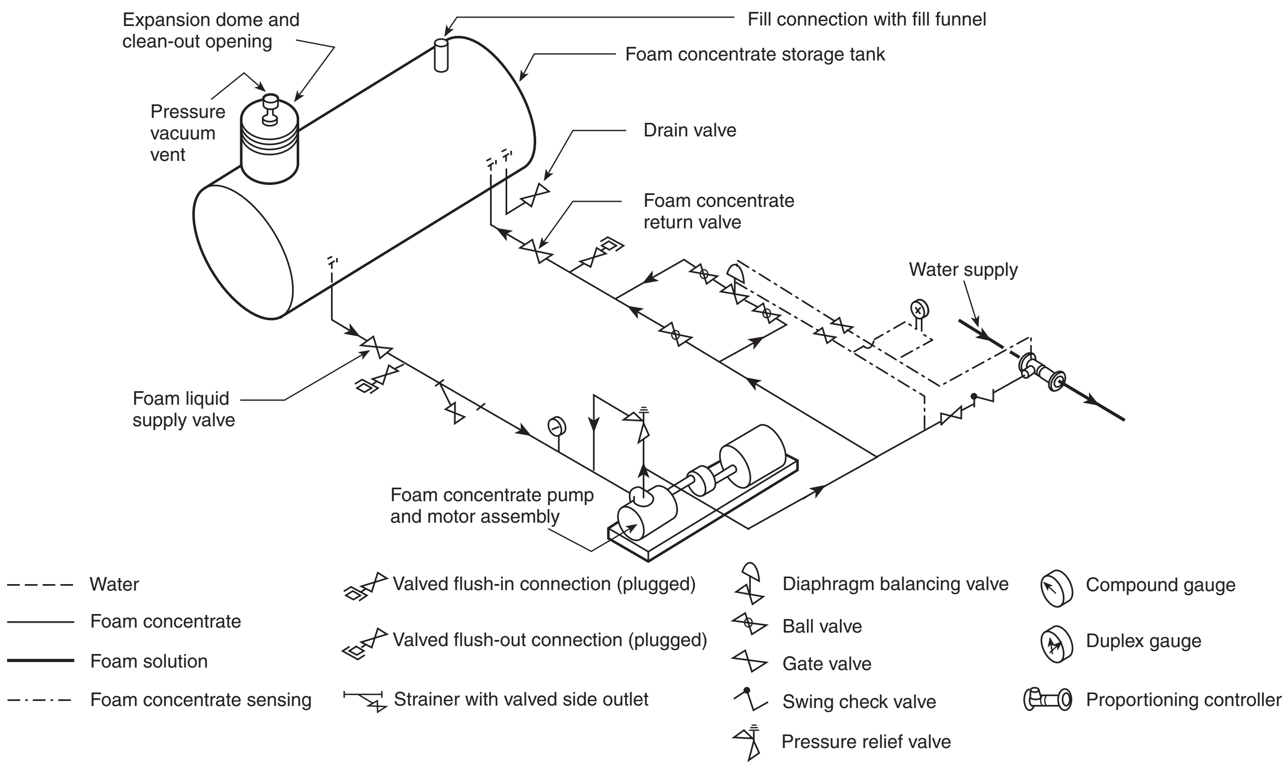

FIGURE A.3.3.24.4(a) Balanced Pressure Proportioning with Single Injection Point (Metered Proportioning).

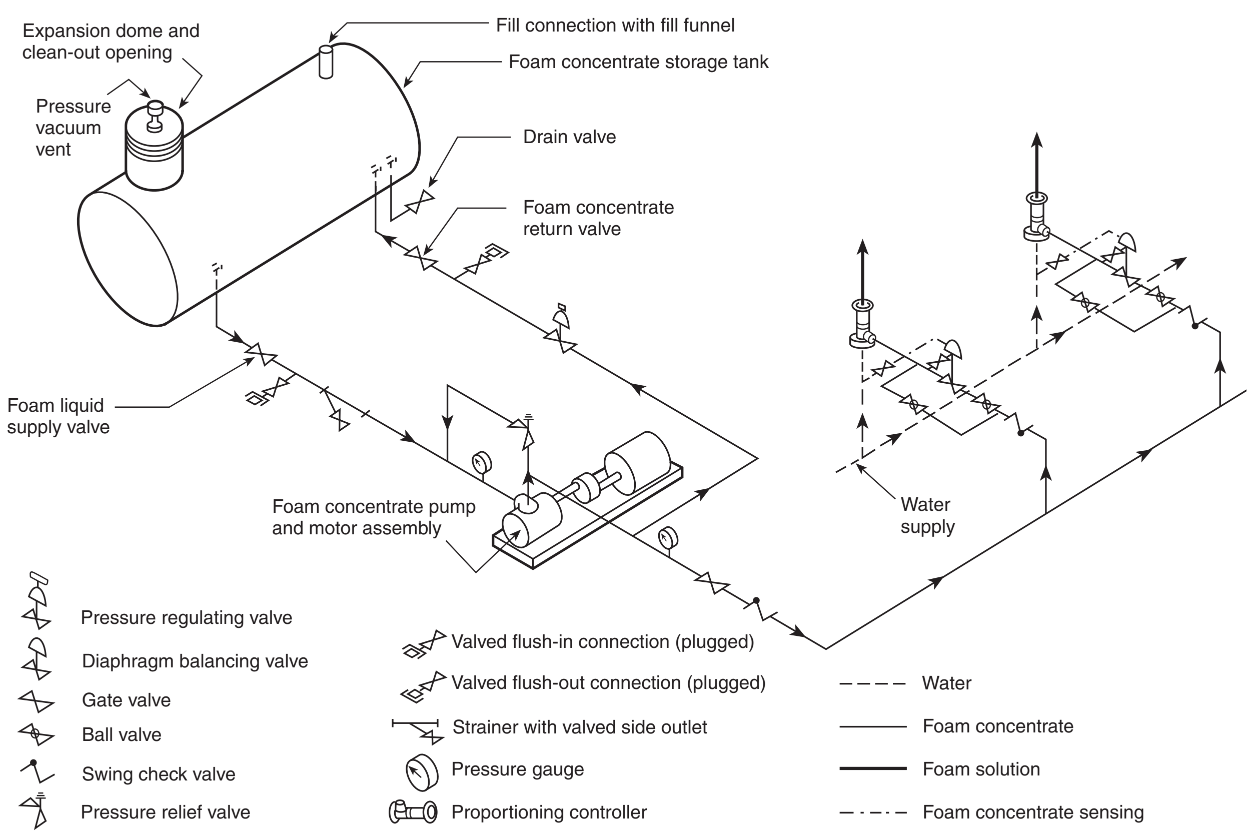

FIGURE A.3.3.24.4(b) Balanced Pressure Proportioning with Multiple Injection Points (Metered Proportioning).

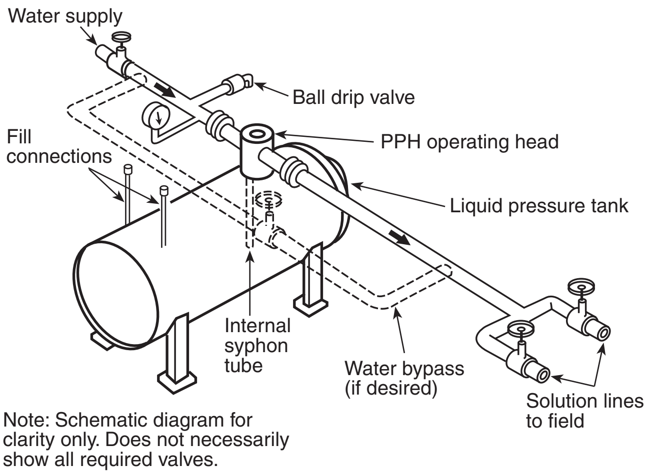

FIGURE A.3.3.24.5(a) Typical Arrangement of Pressure Proportioning Tank.

A.3.3.24.6 Pump Proportioner (Around-the-Pump Proportioner). This device consists of an eductor installed in a bypass line between the discharge and suction of a water pump. A small portion of the discharge of the pump flows through this eductor and draws the required quantity of air foam concentrate from a container, delivering the mixture to the pump suction. Variable capacity can be secured by the use of a manually controlled multiported metering valve. *[See Figure A.3.3.24.6(a).]*

A pump proportioner has the following limitations:

(1) The pressure on the water suction line at the pump must be essentially zero gauge pressure or must be on the vacuum side. A small positive pressure at the pump suction can cause a reduction in the quantity of concentrate educted or cause the flow of water back through the eductor into the concentrate container.
(2) The elevation of the bottom of the concentrate container should not be more than 6 ft (1.8 m) below the proportioner.
(3) The bypass stream to the proportioner uses from 38 L/min to 151 L/min (10 gpm to 40 gpm) of water depending on the size of the device and on the pump discharge pressure. This factor must be recognized in determining the net delivery of the water pump.

Foam Trough. The trough shown schematically in Figure A.3.3.24.6(b) consists of sections of steel sheet formed into a chute securely attached to the inside of the tank wall so that it forms a descending spiral from the top of the tank to within 1.2 m (4 ft) of the bottom. *[See Figure A.3.3.24.6(c) and Figure A.3.3.24.6(d).]*

In Figure A.3.3.24.6(d), note that one brace [13 mm (½ in.) plate, 305 mm (12 in.) long] should be provided at each shell course. This helps maintain the shell in place during the early stages of the fire and prevents buckling before cooling water is applied.

A.4.1.1 A foam system consists of a water supply, a foam concentrate supply, proportioning equipment, a piping system, foam makers, and discharge devices designed to distribute foam effectively over the hazard. Some systems include detection devices.

A.4.2.1.2 Additional water supplies are recommended for cooling the hot tank shell to assist the foam in sealing against the shell. Some foams are susceptible to breakdown and failure to seal as a result of heating the tank shell due to prolonged burning prior to agent discharge.

A.4.2.1.4 Higher or lower water temperatures can reduce foam efficiency.

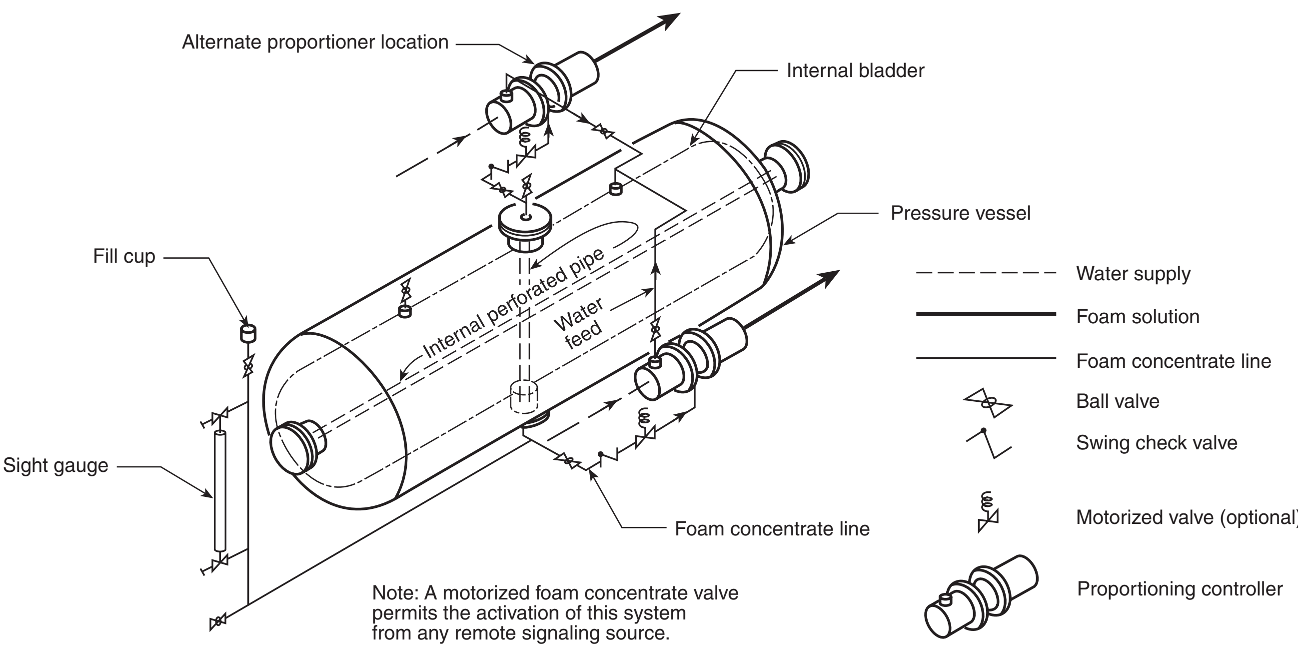

FIGURE A.3.3.24.5(b) Diaphragm (Bladder) Proportioning Tank.

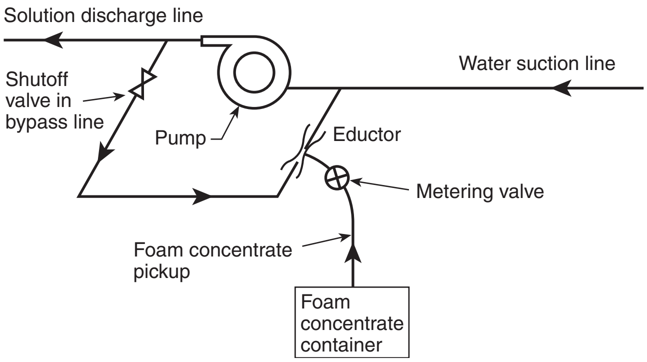

FIGURE A.3.3.24.6(a) Around-the-Pump Proportioner.

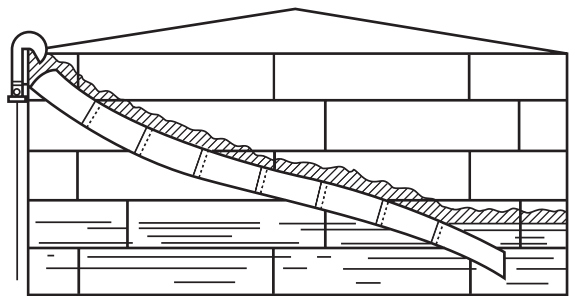

FIGURE A.3.3.24.6(b) Foam Trough.

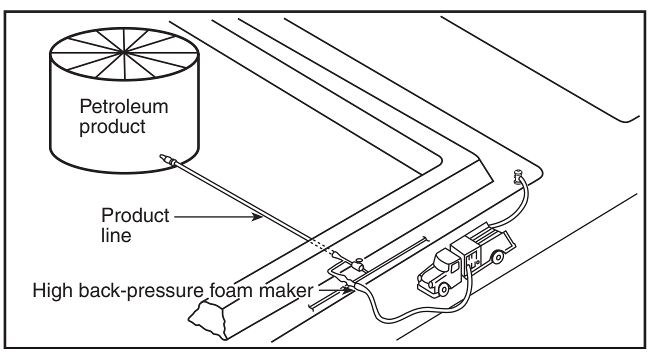

FIGURE A.3.3.24.6(c) Semifixed Subsurface Foam Installation.

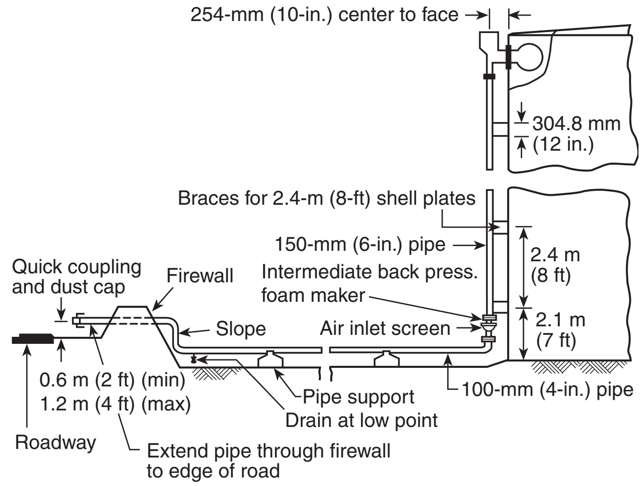

FIGURE A.3.3.24.6(d) Typical Air Foam Piping for Intermediate Back-Pressure Foam System.

A.4.3.1.2 Some concentrates are suitable for use both on hydrocarbon fuels and on water-miscible or polar fuels and solvents.

A.4.3.2.2 The level of concentrate in the storage tank should be monitored to ensure an adequate supply is available at all times.

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

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

A.4.3.2.4.1 Since such systems might or might not be operated for long periods after installation, the choice of proper storage conditions and maintenance methods largely determines the reliability and the degree of excellence of system operation when they are put into service.

A.4.3.2.4.2 Foam concentrates are subject to freezing and to deterioration from prolonged storage at high temperatures. The storage temperature should be monitored to ensure that listed temperature limitations are not exceeded. They can be stored in the containers in which they are transported or can be transferred into large bulk storage tanks, depending on the requirements of the system. The location of stored containers requires special consideration to protect against exterior deterioration due to rusting or other causes. Bulk storage containers also require special design consideration to minimize the liquid surface in contact with air.

A.4.4.1.1 Often different brands of the same type of foam concentrates are found to be chemically compatible. However, before different brands of concentrates are mixed for long-term storage, evaluations should be made to determine such compatibility. A number of parameters should be considered and evaluated before concentrates are mixed for storage. In addition to the chemical compatibility, one should consider effects on proportioning and discharge hardware (many listings and approvals are very specific with regard to operating pressures, flow ranges, and materials of construction of hardware components). The application method should be the same for both foams being mixed. The system design application rate (density) might have to be changed if one of the foam concentrates being admixed is listed or approved at an application rate (density) that is higher than the one used for the initial design. This generally applies to alcohol-resistant foams since their listings and approvals are very application rate sensitive.

A.4.4.2 Some expanded foam is not compatible with all dry chemical agents.

A.4.6 Foam concentrate pumps are generally of the positive displacement variety. Centrifugal pumps might not be suitable for use with foam concentrates exhibiting high-viscosity characteristics. The foam equipment manufacturer should be consulted for guidance.

A.4.7.2.1 Corrosive atmospheres could require other coatings.

A.4.7.3.5 Corrosive atmospheres could require other coatings.

A.4.7.4.3 Welding is preferable where it can be done without introducing fire hazards.

A.4.7.6 A hazard area generally includes all areas within dikes and within 15 m (50 ft) of tanks without dikes. Other areas that should be considered hazard areas include the following:

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

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

Ball valves can be used for foam concentrate proportioning systems.

A.4.8 Basic system types consist of the following:

(1) *Fixed systems.* These systems are complete installations in which foam is piped from a central foam station, discharging through fixed delivery outlets to the hazard to be protected. Any required pumps are permanently installed.
(2) *Semifixed systems.* These systems are the type in which the hazard is equipped with fixed discharge outlets connected to piping that terminates at a safe distance. The fixed piping installation might or might not include a foam maker. Necessary foam-producing materials are transported to the scene after the fire starts and are connected to the piping.
(3) *Mobile systems.* These systems include any type of foam-producing unit that is mounted on wheels and that is self-propelled or towed by a vehicle. These units can be connected to a suitable water supply or can utilize a premixed foam solution. For mobile systems, see NFPA 1901, *Standard for Automotive Fire Apparatus.*
(4) *Portable systems.* These systems are the type in which the foam-producing equipment and materials, hose, and so forth, are transported by hand.

A.4.9.2.5 See applicable sections of *NFPA 72®*, *National Fire Alarm Code®*.

A.4.9.2.6 See NFPA 70, *National Electrical Code®*, Article 500 and other articles in Chapter 5.

A.5.1 There have been cases reported where the application of foam through solid streams that were plunged into the flammable liquid have been believed to be the source of ignition of the ensuing fire. The ignitions have been attributed to static discharges resulting from splashing and turbulence. Therefore, any application of foam to an unignited flammable liquid should be as gentle as possible. Proper application methods with portable equipment might include a spray pattern or banking the foam stream off a backboard so that the foam flows gently onto the liquid surface. Also, properly designed fixed foam chambers on tanks could be expected to deliver the foam fairly gently and not cause a problem.

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

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

These systems are used for the protection of outdoor process and storage tanks. They include the protection of such hazards in manufacturing plants as well as in large tank farms, oil refineries, and chemical plants. These systems usually are designed for manual operation but, in whole or in part, can be automatic in operation. Foam systems are the preferred protection for large outdoor tanks of flammable liquids. *(See Figure A.5.1.)*

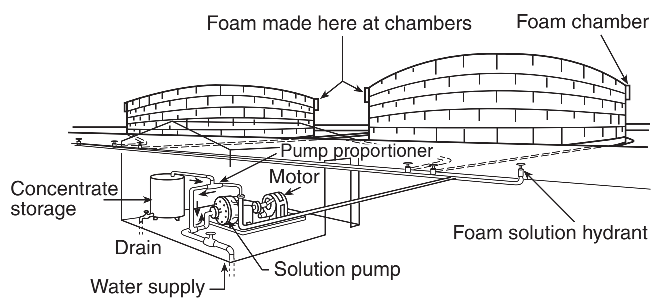

FIGURE A.5.1 Schematic Arrangement of Air Foam Protection for Storage Tanks.

A.5.2.3 The requirements provided in this section are based on extrapolations of test experience and appropriate listings and reflect the limitations known to date.

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

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

A.5.2.4.2.1 The specified minimum delivery rate for primary protection is based on the assumption that all the foam reaches the area being protected.

A.5.2.4.2.2 Where protection is desired for hydrocarbons having a flash point above 93.3°C (200°F), a minimum discharge time of 35 minutes should be used.

A.5.2.4.3 When using some older types of alcohol-resistant foam concentrate, consideration should be given to solution transit time. Solution transit time (i.e., the elapsed time between injection of the foam concentrate into the water and the induction of air) might be limited, depending on the characteristics of the foam concentrate, the water temperature, and the nature of the hazard protected. The maximum solution transit time of each specific installation should be within the limits established by the manufacturer.

A.5.2.4.3.1 In general, alcohol-resistant foams can be effectively applied through foam monitor or foam hose streams to spill fires of these liquids when the liquid depth does not exceed 25.4 mm (1 in.).

A.5.2.4.3.2 If application results in foam submergence, the performance of alcohol-resistant foams usually deteriorates significantly, particularly where there is a substantial depth of fuel. The degree of performance deterioration depends on the degree of water solubility of the fuel (i.e., the more soluble, the greater the deterioration).

A.5.2.5.1 For this application, discharge outlets are commonly called foam chambers. Most foam chambers are of a Type II discharge outlet design, since they are normally suitable for use with modern foams.

A.5.2.5.2.1 It is recommended that, for tanks greater than 60 m (200 ft) in diameter, at least one additional discharge outlet should be added for each additional 465 m^2 (5000 ft^2) of liquid surface or fractional part thereof. Since there has been limited experience with foam application to fires in fixed-roof tanks greater than 42 m (140 ft) in diameter, requirements for foam protection on such tanks are based on the extrapolation of data from successful extinguishments in smaller tanks. Tests have shown that foam can travel effectively across at least 30 m (100 ft) of burning liquid surface. On fixed-roof tanks of over 60-m (200-ft) diameter, subsurface injection can be used to reduce foam travel distances for tanks containing hydrocarbons only.

Unless subsurface foam injection is utilized, a properly sized flanged connection should be installed on all atmospheric pressure storage tanks, regardless of present intended service, to facilitate the future installation of an approved discharge outlet if a change in service should require such installation. Figure A.5.2.5.2.1(a) and Figure A.5.2.5.2.1(b) are typical fixed foam discharge outlets or foam chambers.

A.5.2.5.2.2 Where protection is desired for hydrocarbons having a flash point above 93.3°C (200°F), a minimum time of 15 minutes for Type I outlets and 25 minutes for Type II outlets should be used.

A.5.2.5.3 The system should be designed based on fighting a fire in one tank at a time. The rate of application for which the

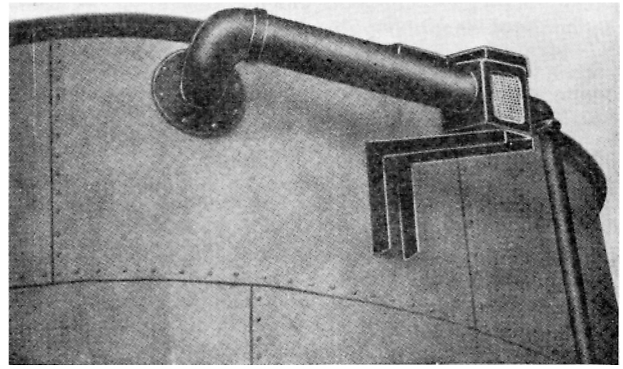

FIGURE A.5.2.5.2.1(a) Air Foam Maker in Horizontal Position at Top of Storage Tank.

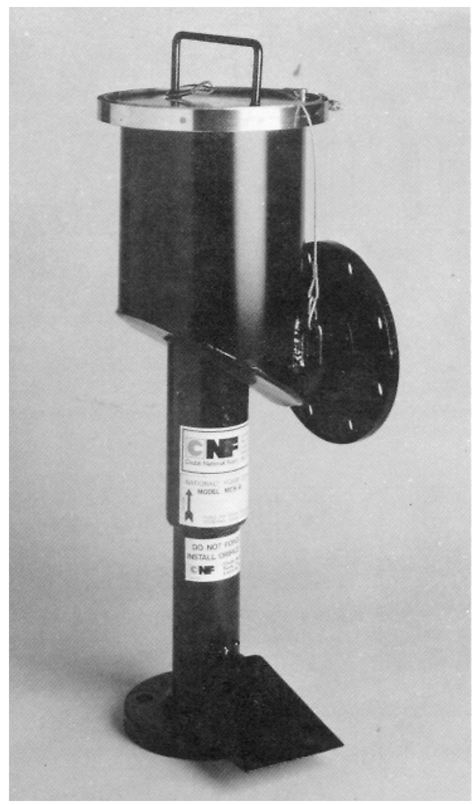

FIGURE A.5.2.5.2.1(b) Foam Chamber and Foam Maker.

system is designed should be the rate computed for the protected tank considering both the liquid surface area and the type of flammable liquid stored.

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

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

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

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

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

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

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

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

A.5.2.5.3.2 Systems using these foams require special engineering consideration.

A.5.2.6.1 Experience with fuel storage tank fire fighting has shown that the main problems are operational (i.e., difficulty in delivering the foam relatively gently to the fuel surface at an application rate sufficient to effect extinguishment). A properly engineered and installed subsurface foam system offers the potential advantages of less chance for foam-generation equipment disruption as a result of an initial tank explosion or the presence of fire surrounding the tank, and the ability to conduct operations a safe distance from the tank. Thus, the opportunity for establishing and maintaining an adequate foam application rate is enhanced. The following guidelines regarding fire attack are recommended.

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

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

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

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

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

Figure A.5.2.6.1(a) and Figure A.5.2.6.1(b) illustrate typical arrangements of semifixed subsurface systems.

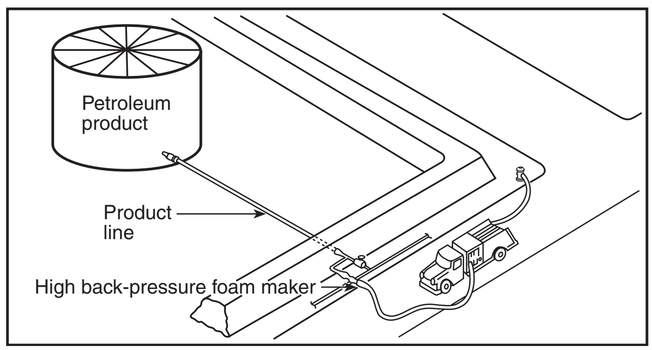

FIGURE A.5.2.6.1(a) Semifixed Subsurface Foam Installation.

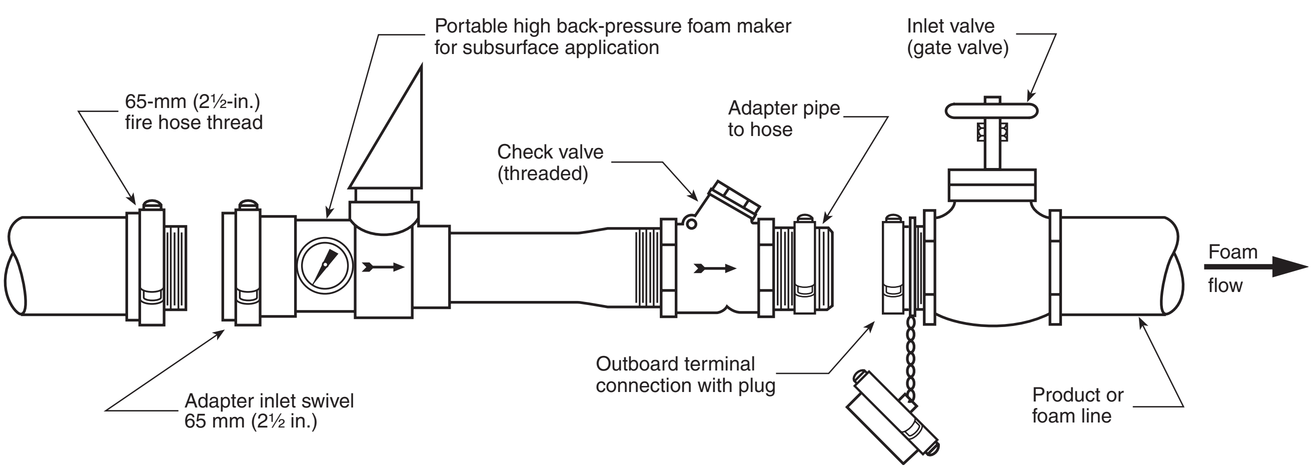

FIGURE A.5.2.6.1(b) Typical Connection for Portable High Back-Pressure Foam Maker for Subsurface Application in Semifixed System.

A.5.2.6.2 Figure A.5.2.6.2(a) through Figure A.5.2.6.2(c) should be used to determine foam velocity.

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

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

where:
A = area of ID of the injection pipe (ft^2)
K = constant 449
gpm = gallons per minute

or

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

where:
d = pipe ID (in.)

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

where:
d = pipe ID (mm)

Figure A.5.2.6.2(d) illustrates optional arrangements for multiple subsurface discharge outlets.

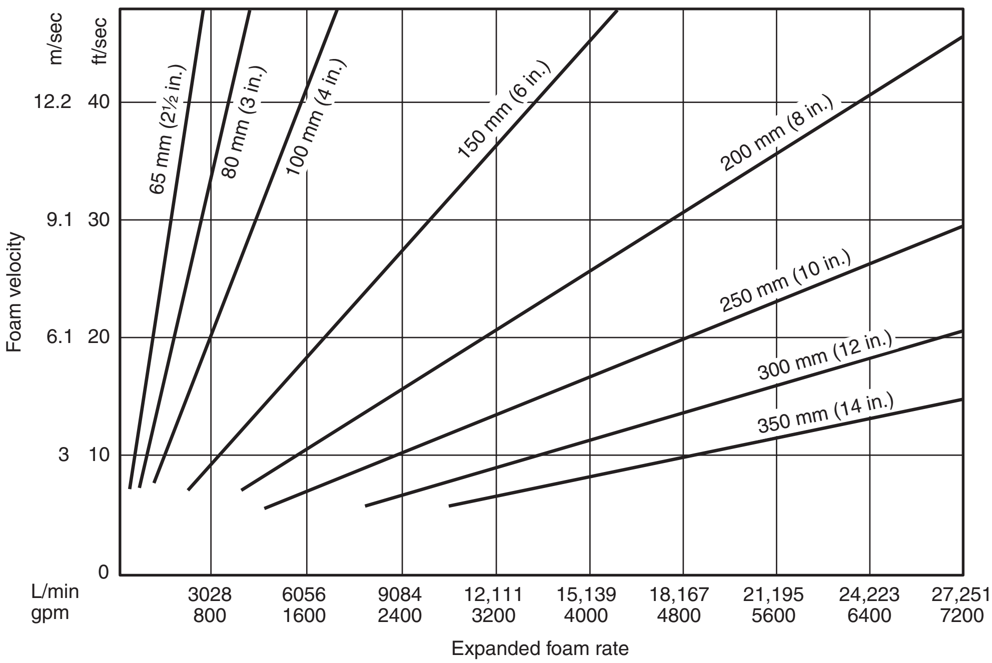

FIGURE A.5.2.6.2(a) Foam Velocity vs. Pipe Size (2½ in., 3 in., 4 in., 6 in., 8 in., 10 in., 12 in., and 14 in.) — Standard Schedule 40 Pipe.

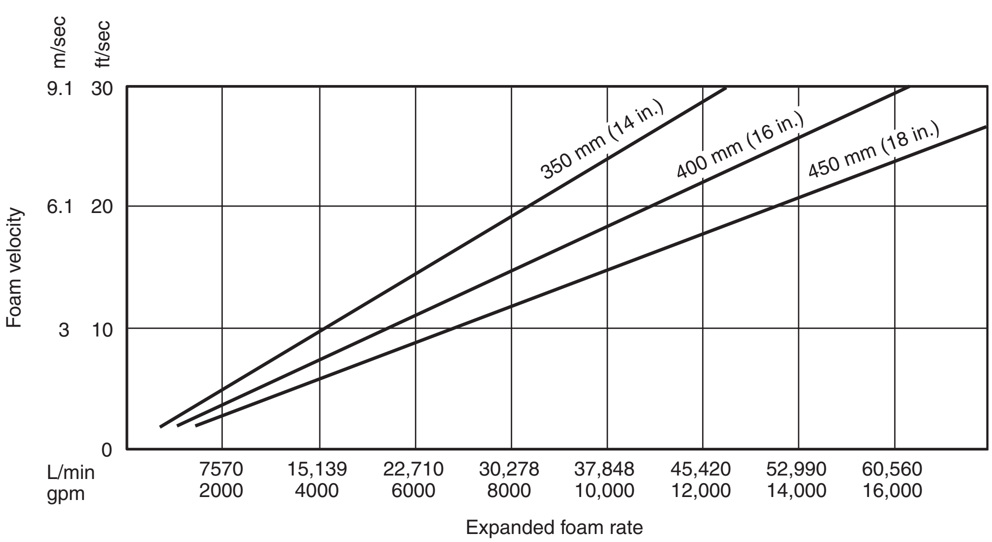

FIGURE A.5.2.6.2(b) Foam Velocity vs. Pipe Size (14 in., 16 in., and 18 in.) — Standard Schedule 40 Pipe.

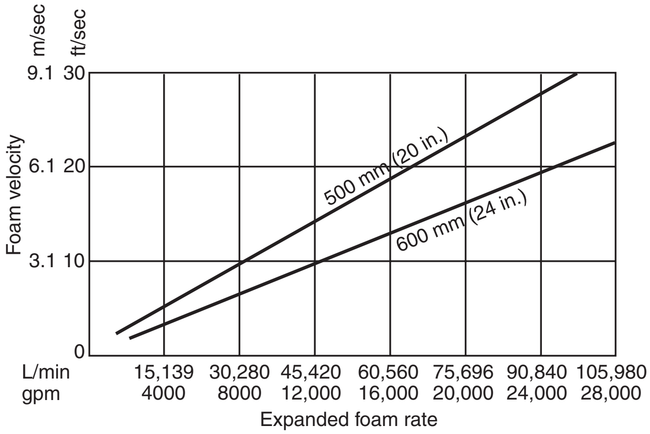

FIGURE A.5.2.6.2(c) Foam Velocity vs. Pipe Size (20 in. and 24 in.) — Standard Schedule 40 Pipe.

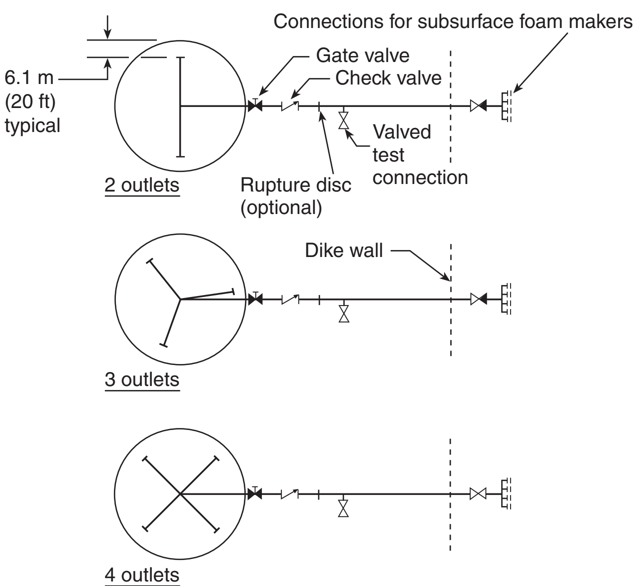

FIGURE A.5.2.6.2(d) Typical Arrangement of Semifixed Subsurface System.

A.5.2.6.3 Figure A.5.2.6.3 illustrates a typical foam inlet tank connection.

A.5.2.6.3.1 Liquid hydrocarbons that contain foam-destructive products might require higher application rates. Some foams might fail to extinguish fires in gasolines containing oxygenates where using subsurface discharge at the usually required rate.

Optimum fluoroprotein foam, AFFF, and FFFP characteristics for subsurface injection purposes should have expansion ratios between 2 and 4. *[See Figure A.5.2.6.3.1(a) and Figure A.5.2.6.3.1(b).]*

A.5.2.6.4 The back-pressure consists of the static head plus pipe friction losses between the foam maker and the foam inlet to the tank. The friction loss curves *[see Figure A.5.2.6.4(a) and Figure A.5.2.6.4(b)]* are based on a maximum foam expansion of 4, which is the value to be used for friction loss and inlet velocity calculations.

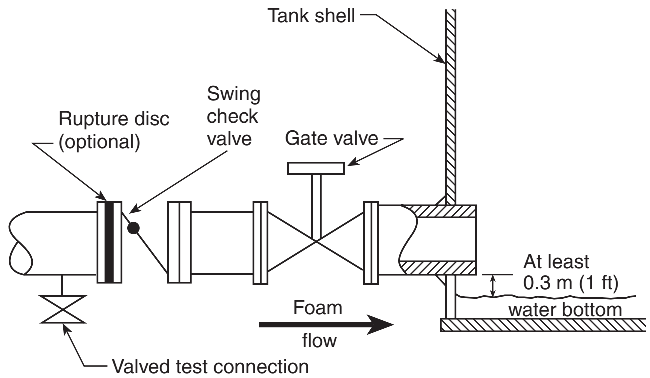

FIGURE A.5.2.6.3 Typical Tank Foam-Maker Discharge Connection for Subsurface Injection.

A.5.2.6.5.2 Liquid hydrocarbons that contain foam-destructive products might require higher application rates. Some foams might fail to extinguish fires in gasolines containing oxygenates where using subsurface discharge at the usually required rate.

A.5.2.7 This section describes the design criteria that are applicable to systems used to apply foam to the surface of fixed-roof (cone) storage tanks via a flexible hose rising from the base of the tank. Manufacturer recommendations should be followed for the design and installation of such systems. *(For semisubsurface system arrangement, see Figure A.5.2.7.)*

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

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

(1) The total foam output should reach the surface of the burning liquid.
(2) With large tanks, the semisubsurface units can be arranged to produce an even distribution over the fuel surface.
(3) Any type of concentrate suitable for gentle surface application to the particular fuel can be used.
(4) Foam-generating equipment and operating personnel can be located at a distance from the fire.
(5) The system can be used for the protection of foam destructive liquids, provided the flexible hose is not affected by them.
(6) Certain high-viscosity fuels might not be suitable for protection by this type of system.
(7) There is no circulation of the cold fuel and, therefore, no assistance in extinguishment.
(8) The system can be difficult to check, test, and maintain.
(9) The high back-pressure foam generator has to produce foam at a pressure sufficient to overcome the head pressure of fuel as well as all friction losses in the foam pipework. Friction losses with foam differ from those with foam solution.

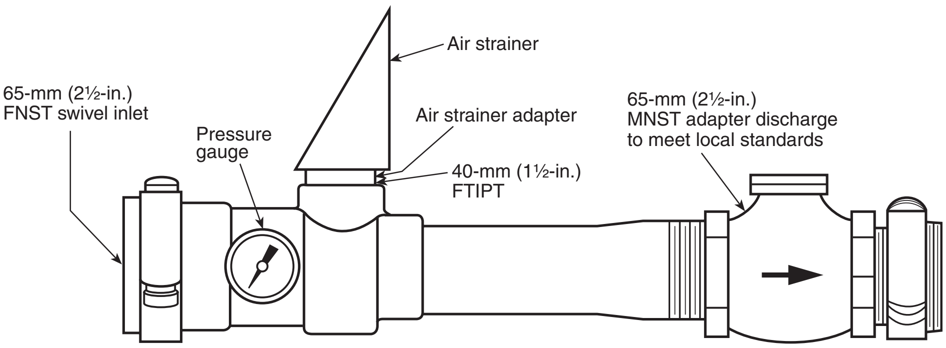

FIGURE A.5.2.6.3.1(a) Portable High Back-Pressure Foam Maker for Semifixed Systems.

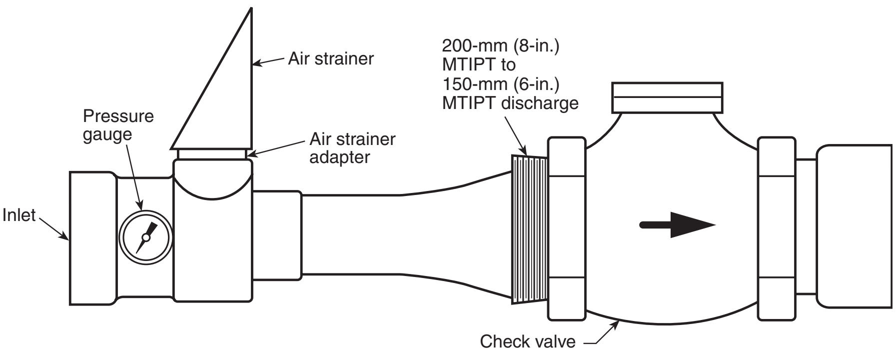

FIGURE A.5.2.6.3.1(b) Fixed High Back-Pressure Foam Maker for Fixed Systems.

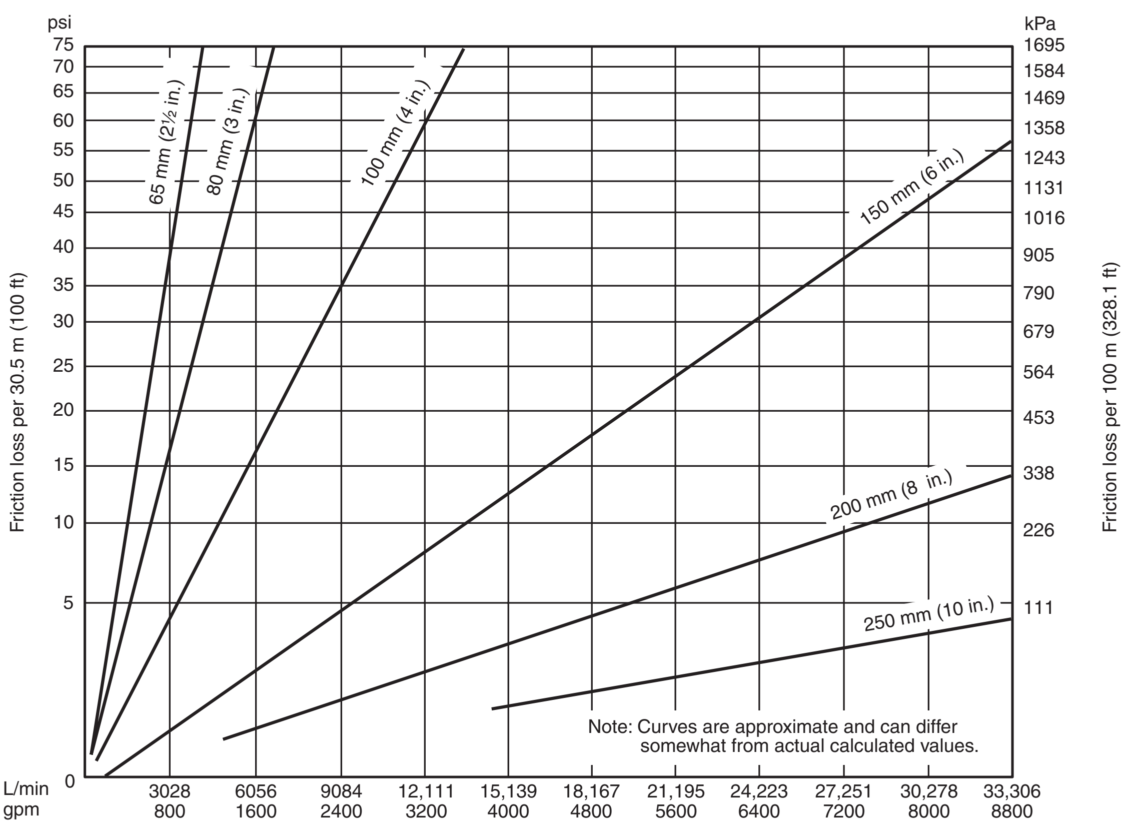

FIGURE A.5.2.6.4(a) Foam Friction Losses — 4 Expansion (2½ in., 3 in., 4 in., 6 in., 8 in., and 10 in.) — Standard Schedule 40 Pipe.

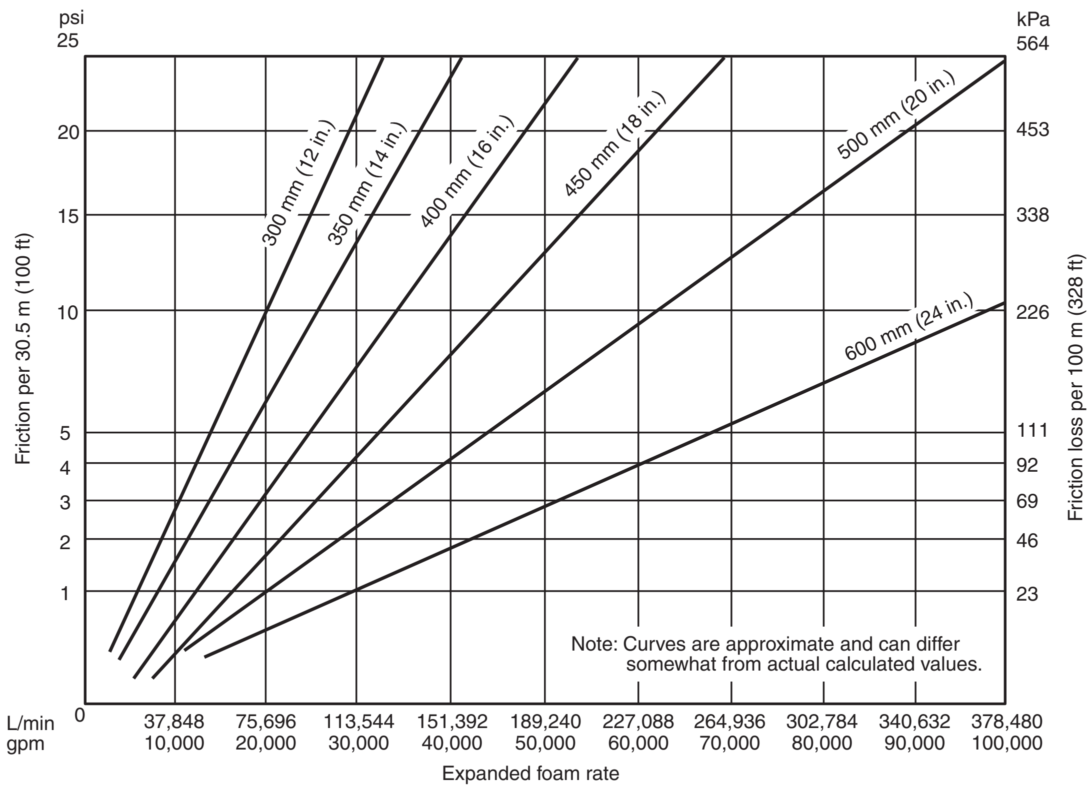

FIGURE A.5.2.6.4(b) Foam Friction Losses — 4 Expansion (12 in., 14 in., 16 in., 18 in., 20 in., and 24 in.) — Standard Schedule 40 Pipe.

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

Duration of discharge should be in accordance with Table A.5.2.7(a).

Semisubsurface foam units should be spaced equally, and the number of units should be in accordance with Table A.5.2.7(b).

Table A.5.2.7(a) Duration of Discharge for Semisubsurface Systems

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

Table A.5.2.7(b) Minimum Number of Subsurface Units

Tank Diameter		Minimum Number of Semisubsurface Units
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)

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

A.5.3 Within the scope of this standard, open-top floating roof tanks are defined as vertical cylindrical tanks without fixed roofs that have double-deck or pontoon-type floating roofs and are constructed in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*. The seal can be a mechanical shoe seal or tube seal. The tube seal

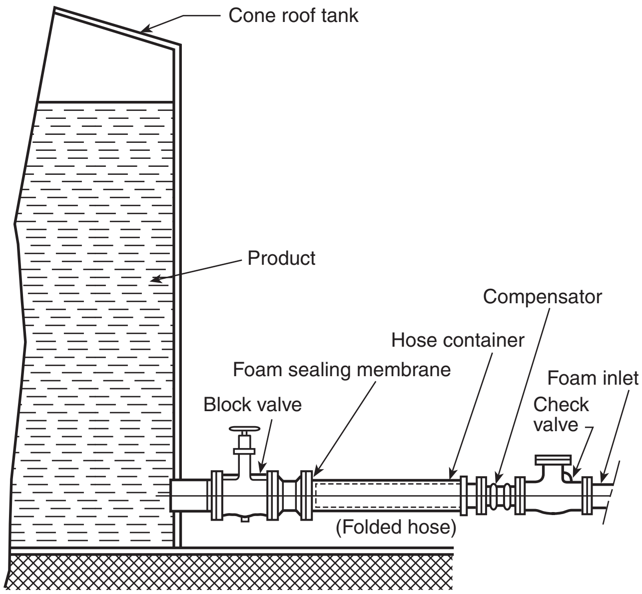

FIGURE A.5.2.7 Semisubsurface System Arrangement.

can be equipped with a metal weather shield. Secondary seals of combustible or noncombustible materials can also be installed. *[See Figure 5.3(a) through Figure 5.3(d).]*

A.5.3.3 Open-top floating roof tanks can experience two distinct types of fires: a seal fire or a full surface area fire (as a result of the floating roof sinking). Experience indicates that the most frequent type of fire involves only the seal of the floating roof tank. Prior to selecting the method of protection, the type of fire that will serve as the basis for design should be defined. *(See NFPA 30, Flammable and Combustible Liquids Code, for fire protection requirements.)*

Most fires in open-top floating roof tanks occur in the seal areas, and these fires can be extinguished with the foam systems described in Chapter 5. However, some fires involve the full surface area when the roof sinks. These fires are very infrequent and normally do not justify a fixed system to protect for this risk. Plans should be made to fight a full surface fire in a floating roof tank with portable or mobile equipment. Large capacity foam monitor nozzles with capacities up to 22,712 L/min (6000 gpm) are currently available. If foam-proportioning devices are not provided with the foam monitors, additional foam-proportioning trucks might be required through mutual aid. Generally, the number of foam-proportioning trucks available at any location is not sufficient to fight a sunken floating roof fire, and outside assistance is required.

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

Another aspect to consider is the amount of foam concentrate available. The foam application rate of 6.5 $L/min \cdot m^2$ (0.16 gpm/ft^2) of surface area listed in Chapter 5 might have to be increased for very large tanks. Therefore, the amount of foam concentrate available through mutual aid should be established prior to the fire. In some cases, it can be necessary to increase the on-site foam storage if mutual aid supplies are limited.

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

A.5.3.4.3 The requirements given in this section are based on extrapolations of test experience and appropriate listings and reflect the limitations known to date.

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

A.5.3.5.2 See Figure A.5.3.5.2.3(a) and Figure A.5.3.5.2.3(b).

A.5.3.5.2.3 Since all the discharge outlets are supplied from a common (ring) foam solution main, some vapor seal devices might not rupture due to pressure variations encountered as the system is activated. *[See Figure A.5.3.5.2.3(a) and Figure A.5.3.5.2.3(b).]*

A.5.3.5.4.5 See Figure 5.3.5.4.5.

A.5.3.6 Use of foam handlines for the extinguishment of seal fires should be limited to open-top floating roof tanks of less than 76.2 m (250 ft) in diameter. The following design information applies to foam handline protection methods:

(1) A foam dam should be installed in accordance with 5.3.5.4.
(2) To establish a safe base for operation at the top of the tank, a single fixed foam discharge outlet should be installed at the top of the stairs. This fixed foam discharge outlet is meant to provide coverage of the seal area for approximately 12.2 m (40 ft) on both sides of the top of the stairs.
(3) The fixed foam discharge outlet should be designed to discharge at least 189.3 L/min (50 gpm).
(4) To permit use of foam handlines from the windgirder, two 38.1-mm (1.5-in.) diameter valved hose connections should be provided at the top of the stairs in accordance with Figure A.5.3.6.

The windgirder should be provided with a railing for the safety of the fire fighters. *(See Figure A.5.3.6.)*

A.5.4 Within the scope of this standard, covered (internal) floating roof tanks are defined as vertical cylindrical tanks with a fixed metal roof (cone or geodesic dome) equipped with ventilation at the top and containing a metal double-deck or pontoon-type floating roof or a metal floating cover supported by liquidtight metal flotation devices. They are constructed in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code. (See Figure 5.4.)*

A.5.4.2.2.4 The hazard requiring the highest foam solution flow rate does not necessarily dictate the total amount of foam concentrate required.

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

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

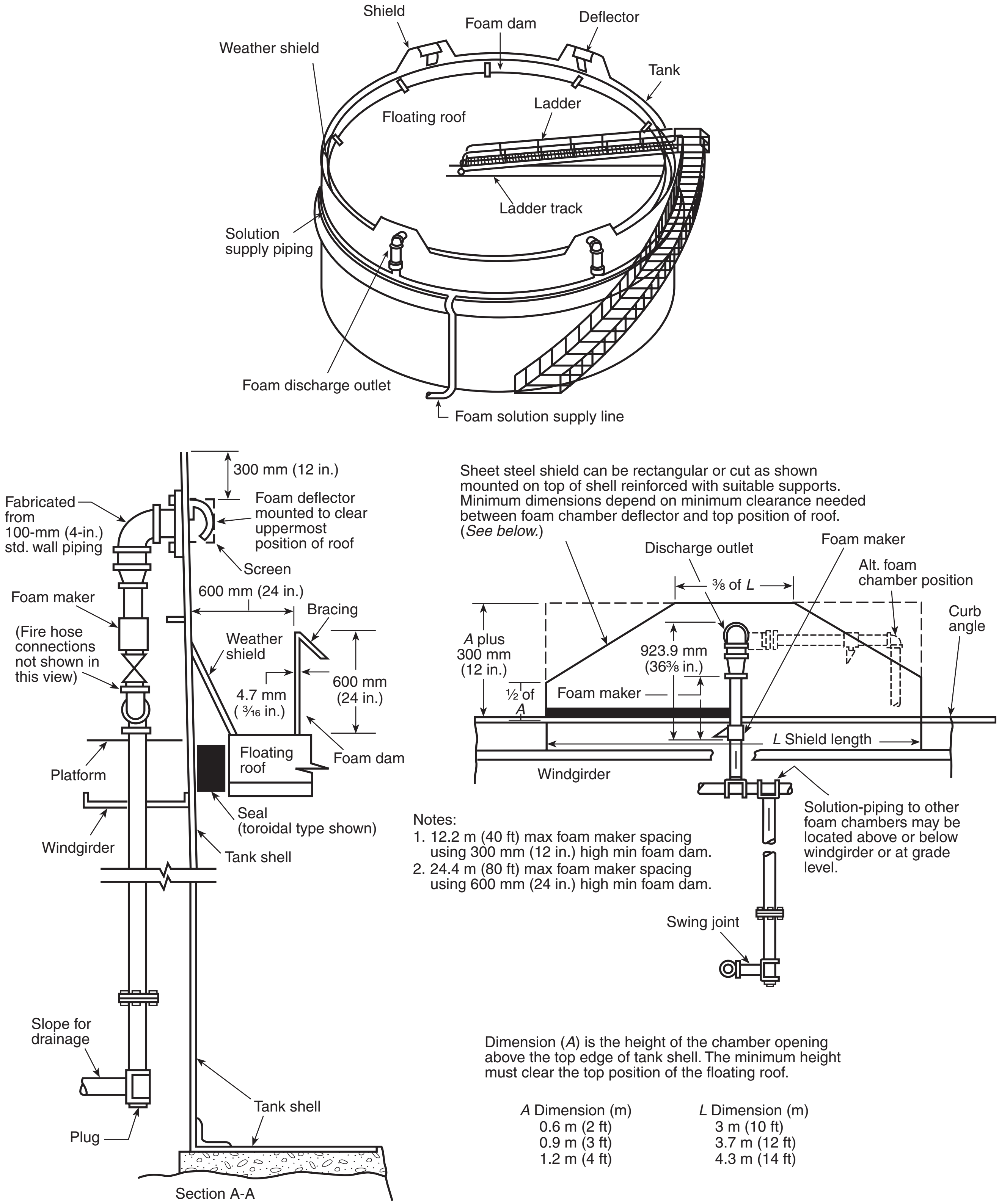

FIGURE A.5.3.5.2.3(a) Typical Foam Splash Board for Discharge Devices Mounted Above the Top of the Shell.

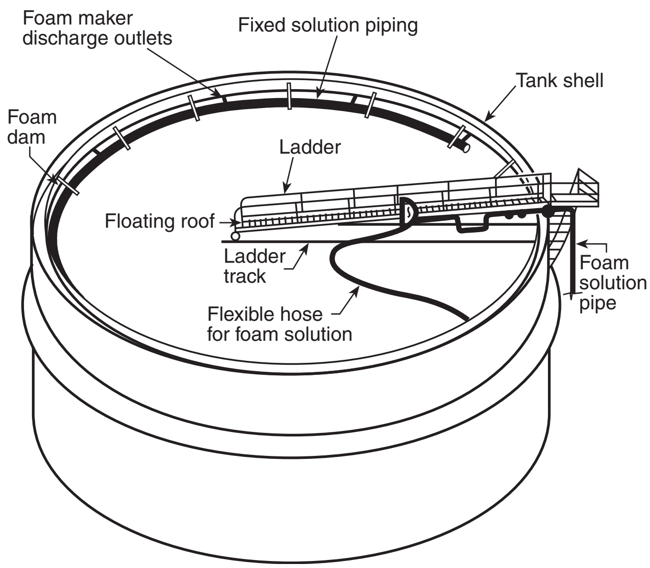

FIGURE A.5.3.5.2.3(b) Fixed Foam Discharge Outlets Mounted on the Periphery of the Floating Roof.

A.5.5.1 For other types of indoor hazards, see the design criteria requirements of NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*.

A.5.5.4.1 Systems using these foams require special engineering consideration.

A.5.6 To minimize life and property loss, automation of foam systems protecting a truck loading rack should be taken into account. NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, states that "Automatic operation shall be provided and supplemented by auxiliary manual tripping means."

Manual operation only can be provided when acceptable to the authority having jurisdiction.

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

(1) Completely automatic detection and actuation *(See applicable sections of NFPA 72, National Fire Alarm Code, for design criteria.)*
(2) Actuation by push-button stations or other means of manual release.

The speed of system operation is always critical in minimizing life and property loss.

A.5.6.5.1 The proper choice of each monitor location is a very important factor in designing a foam monitor system. Traffic patterns, possible obstructions, wind conditions, and effective foam nozzle range affect the design. The appropriate monitors and nozzles should be located so that foam is applied to the entire protected area at the required application rate.

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

A.5.6.5.2 Although most systems are designed to protect the canopy area only, it is often desirable to protect the total curbed area around the loading rack or the entire length of the truck or rail car.

A.5.7 Generally, portable monitors or foam hose streams or both have been adequate in fighting spill fires in diked areas. In order to obtain maximum flexibility due to the uncertainty of location and the extent of a possible spill in process areas and tank farms, portable or trailer-mounted monitors are more practical than fixed foam systems in covering the area involved. The procedure for fighting diked area spill fires is to extinguish and secure one area and then move on to extinguish the next section within the dike. This technique should be continued until the complete dike area has been extinguished.

A.5.7.3.2 Fixed foam discharge outlets vary considerably in capacity and range area of coverage.

A.5.7.3.3.2 Overhead application by foam-water sprinklers or nozzles could need supplementary low-level foam application to provide coverage below large obstructions. Overhead pipework can be susceptible to damage by explosion. Overhead application by foam-water sprinklers or nozzles might need supplementary low-level foam application to provide coverage below large obstructions. Overhead pipework can be susceptible to damage by explosion.

A.5.7.3.4.3 Low-level foam discharge outlets might need supplementary overhead foam spray application to provide coverage or cooling for overhead structures or for tank surfaces.

A.5.8 In such cases it is assumed that any fire would be classified as a spill fire [i.e., one in which the flammable liquid spill has an average depth not exceeding 25.4 mm (1 in.) and is bounded only by the contour of the surface on which it is lying].

A.5.9 Auxiliary foam hose streams can be supplied directly from the main system protecting the tanks (e.g., centralized fixed pipe system) or can be provided by additional equipment. The supplementary hose stream requirements provided herein are not intended to protect against fires involving major fuel spills; rather, they are considered only as first aid-type protection for extinguishing or covering small spills involving areas in square meters (square feet) equal to those covered by about six times the rated capacity [in L/min (gpm)] of the nozzle.

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

A.6.1 It is good practice for the owner or his or her designated representative (i.e., architect, contractor, or other authorized person) to review the basic hazard with the authority having jurisdiction to obtain guidance and preliminary approval of the proposed protection concept.

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

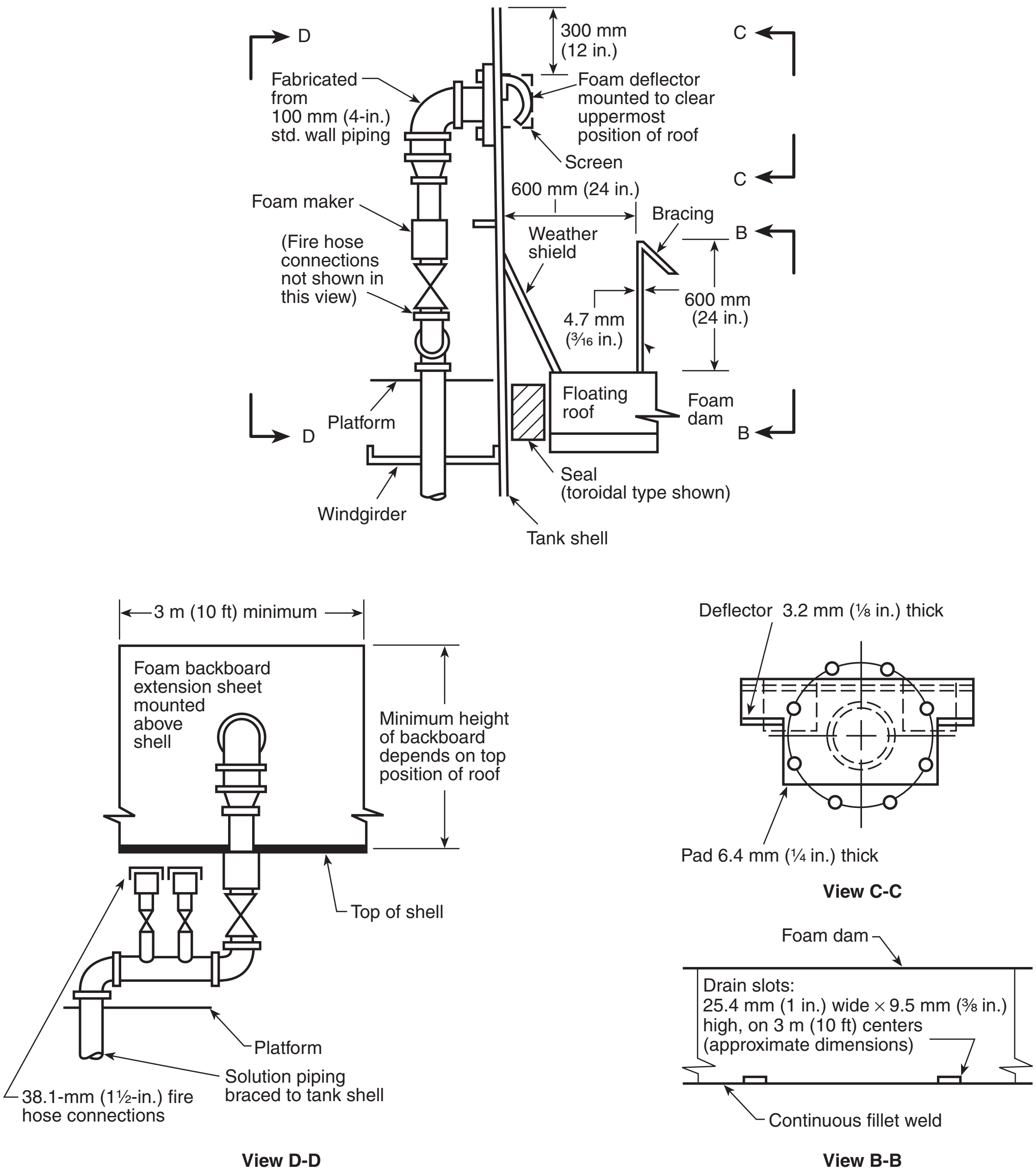

FIGURE A.5.3.6 Typical Installation of Foam Handlines for Seal Area Fire Protection.

A.6.3.4(6) See Chapter 9 of NFPA 13, *Standard for the Installation of Sprinkler Systems*, for hydraulic calculation procedures.

A.7.3.4 Limited service controllers generally do not have a service disconnect means. In order to perform routine inspection and maintenance safely, it might be desirable to provide an external service disconnect. Special care must be taken to ensure the disconnect is not left in a position rendering the foam concentrate pump inoperable.

A.7.4.1.3(2) This riser can be welded to the tank by means of steel brace plates positioned perpendicular to the tank and centered on the riser pipe.

A.7.4.1.4 With all welded construction, this could be the only joint that can be opened.

A.8.2 High-expansion foam is an agent for control and extinguishment of Class A and Class B fires and is particularly suited as a flooding agent for use in confined spaces. Development of the use of high-expansion foams for fire-fighting purposes started with the work of the Safety in Mines Research Establishment of Buxton, England, based on the difficult problem of fires in coal mines. It was found that by expanding an aqueous surface active agent solution to a semistable foam of about 1000 times the volume of the original solution, it was possible to force the foam down relatively long corridors, thus providing a means for transporting water to a fire inaccessible to ordinary hose streams.

This work led to the development of specialized high-expansion foam-generating equipment for fighting fires in mines, for application in municipal industrial fire fighting, and for the protection of special hazard occupancies. Medium-expansion foam was developed to meet the need for a foam that was more wind resistant than high-expansion foam for outdoor applications.

Description. Medium- and high-expansion foams are aggregations of bubbles that are mechanically generated by the passage of air or other gases through a net, screen, or other porous medium that is wetted by an aqueous solution of surface active foaming agents. Under proper conditions, fire-fighting foams of expansions from 20:1 to 1000:1 can be generated. These foams provide a unique agent for transporting water to inaccessible places; for total flooding of confined spaces; and for volumetric displacement of vapor, heat, and smoke. Tests have shown that, under certain circumstances, high-expansion foam, when used in conjunction with water sprinklers, will provide more positive control and extinguishment than either extinguishment system by itself. High-piled storage of rolled paper stock is an example. Optimum efficiency in any one type of hazard depends to some extent on the rate of application and the foam expansion and stability.

Medium- and high-expansion foams, which are generally made from the same type of concentrate, differ mainly in their expansion characteristics.

Medium-expansion foam can be used on solid fuel and liquid fuel fires where some degree of in-depth coverage is necessary — for example, for the total flooding of small enclosed or partially enclosed volumes such as engine test cells and transformer rooms. Medium-expansion foam can provide quick and effective coverage of flammable liquid spill fires or some toxic liquid spills where rapid vapor suppression is essential. It is effective both indoors and outdoors.

High-expansion foam can also be used on solid- and liquid-fuel fires, but the in-depth coverage it provides is greater than for medium-expansion foam. Therefore, it is most suitable for filling volumes in which fires exist at various levels. For example, experiments have shown that high-expansion foam can be used effectively against high-rack storage fires, provided that the foam application is started early and the depth of foam is rapidly increased. It also can be used to extinguish fires in enclosures, such as in basement and underground passages, where it might be dangerous to send personnel. It can be used to control fires involving liquefied natural gases (LNGs) and liquefied petroleum gases (LPGs) and to provide vapor dispersion control for LNG and ammonia spills.

High-expansion foam is particularly suited for indoor fires in confined spaces. Its use outdoors can be limited because of the effects of wind and lack of confinement. Medium- and high-expansion foam have the following effects on fires:

(1) Where generated in sufficient volume, medium- and high-expansion foam can prevent the free movement of air, which is necessary for continued combustion.
(2) Where forced into the heat of a fire, the water in the foam is converted to steam, thus reducing the oxygen concentration by dilution of the air.
(3) The conversion of the water to steam absorbs heat from the burning fuel. Any hot object exposed to the foam will continue the process of breaking the foam, converting the water to steam, and cooling.
(4) Because of its relatively low surface tension, solution from the foam that is not converted to steam will tend to penetrate Class A materials. However, deep-seated fires might require overhaul.
(5) Where accumulated in depth, medium- and high-expansion foam can provide an insulating barrier for protection of exposed materials or structures not involved in a fire and can thus prevent fire spread.
(6) For LNG fires, high-expansion foam will not normally extinguish a fire, but it will reduce the fire intensity by blocking radiation feedback to the fuel.
(7) Class A fires are controlled when the foam completely covers the fire and burning material. If the foam is sufficiently wet and is maintained long enough, the fire can be extinguished.
(8) Class B fires involving high-flash-point liquids can be extinguished when the surface is cooled below the flash point. Class B fires involving low-flash-point liquids can be extinguished when a foam blanket of sufficient depth is established over the liquid surface.

Refrigerated or cryogenic liquefied flammable gas fires can be safely controlled, and vapor concentrations downwind of unignited spills can be reduced by application of high-expansion foam when the vapor density at ambient temperature and pressure is less than that of air.

High-expansion foam should not be applied to refrigerated liquefied petroleum gas (LPG) fires unless careful consideration is given to the resulting possibly hazardous condition. Extinguishment can occur with evolution of heavier-than-air vapors beneath the foam blanket. The vapors will accumulate or drain from beneath the foam blanket to low areas with the danger of vapor cloud formation or reignition or both.

For LPG fire control, see *Control and Extinguishment of LPG Fires*, D. W. Johnson, et al.

A.8.3.2 Under certain circumstances, it might be possible to utilize medium- or high-expansion foam systems for control of fires involving flammable liquids or gases issuing under pressure, but no general recommendations can be made in this standard due to the infinite variety of particular situations that can be encountered in actual practice.

Ability to control or extinguish a fire in a given hazard might depend on such factors as expansion, drainage, and fluidity. These factors will vary with the concentrate, equipment, water supply, and air supply.

A.8.6 The discharge of large amounts of medium- or high-expansion foam can inundate personnel, while blocking vision, making hearing difficult, creating some discomfort in breathing, and causing spatial disorientation. This breathing discomfort will increase with a reduction in expansion ratio of the foam while the foam is under the effect of sprinkler discharge.

A.8.6.1 Additional exits and other measures might be necessary to ensure safe evacuation of personnel.

A.8.6.1.1 The foam is opaque, making it impossible to see when one is submerged in it. It is dangerous to enter a building in which there was a fire if one cannot see.

A.8.6.1.2 The chemicals of the canister can react with the water of the foam and cause suffocation.

A.8.6.2 As used in this standard, "clearance" is the air distance between medium- or high-expansion foam equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential. Since medium- or high-expansion foams are conductive, these clearances do not prevent conduction through foam. *(See 8.6.1.3.)*

Up to electrical system voltages of 161 kV, the design BIL kV and corresponding minimum clearances, phase to ground, have been established through long use.

A.8.7.2 Fires or conditions likely to produce fire can be detected by human senses or by automatic means.

A.8.7.2.2 See *NFPA 72, National Fire Alarm Code.*

A.8.7.2.3 See applicable provisions of *NFPA 72, National Fire Alarm Code*, for power supply requirements.

A.8.7.5 A block diagram of a typical automatic medium- or high-expansion foam system is shown in Figure A.8.7.5(a). At the present time, foam generators for medium- and high-expansion foam are of two types, depending on the means for introducing air — by aspirator or blower. In either case, the properly proportioned foam solution is made to impinge at appropriate velocity on a screen or porous or perforated membrane or series of screens in a moving airstream. The liquid films formed on the screen are distended by the moving airstream to form a mass of bubbles or medium- or high-expansion foam. The foam volume varies from about 20 to 1000 times the liquid volume, depending on the design of the generator. The capacity of foam generators is generally determined by the time required to fill an enclosure of known volume by top application within 1 to 5 minutes.

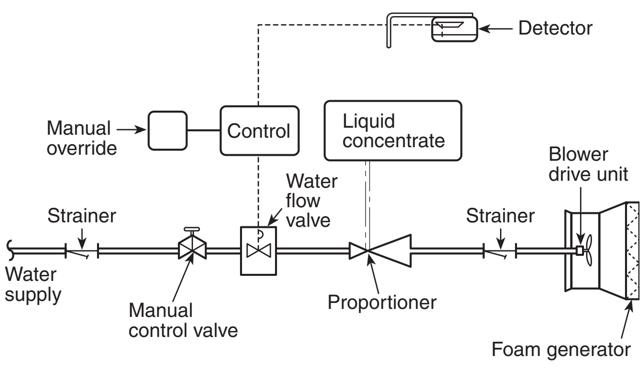

FIGURE A.8.7.5(a) Block Diagram of Automatic Medium- or High-Expansion Foam System.

Foam Generators — Aspirator Type. Foam generators can be fixed or portable. Jet streams of foam solution aspirate sufficient amounts of air that is then entrained on the screens to produce foam. *[See Figure A.8.7.5(b).]* These generators usually produce foam with expansion rations of not more than 250:1.

Foam Generators — Blower Type. Foam generators can be fixed or portable. The foam solution is discharged as a spray onto screens through which an airstream developed by a fan or blower is passing. The blower can be powered by electric motors, internal combustion engines, air, gas, or hydraulic motors or water motors. The water motors are usually powered by foam solution. *[See Figure A.8.7.5(c).]*

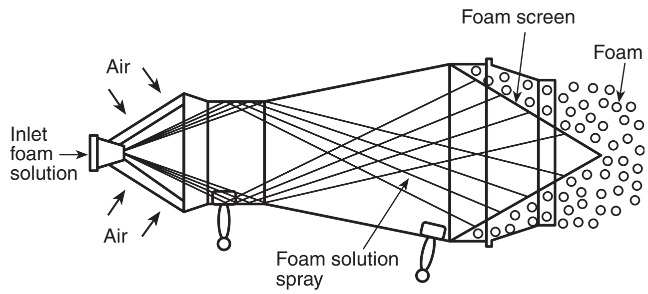

FIGURE A.8.7.5(b) Aspirating-Type Foam Generator.

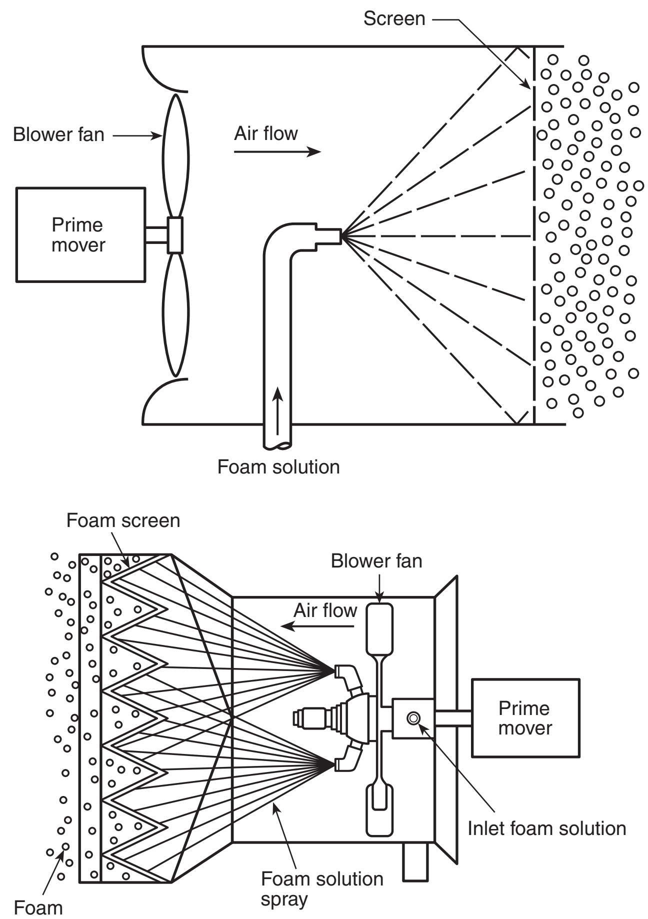

FIGURE A.8.7.5(c) Blower-Type Foam Generators.

A.8.8.2.1 The use of salt water or hard water or the presence of corrosion inhibitors, antifreeze agents, marine growths, oil, or other contaminants can result in reduction of foam volume or stability.

A.8.8.8 Exposure of the foam concentrate to the atmosphere can cause evaporation of some or all components of the concentrate and, in some cases, can cause crusting of the agent. This condition is exaggerated when a tank with an open vent is located in an area where the temperature fluctuates. For example, sunlight striking a tank during the day will cause the concentrate to expand and some concentrate vapors to escape. When the tank cools at night, fresh will be drawn in to replace the lost vapors. Over a period of time, the amount and the composition of the concentrate can change. This loss can be minimized by designing the concentrate tank to include the following:

(1) An expansion dome that reduces the free surface of the concentrate to an area much smaller than the tank
(2) A pressure-vacuum valve that reduces the amount of escaping vapors and also reduces the amount of fresh air entering the tank

A.8.10.2 *Resistance of Foam Generators to Fire Exposure.* To determine its ability to withstand fire exposure from the hazard area, a generator and its associated piping and electrical wiring, protected in accordance with the manufacturers' recommendations, should be started and operated satisfactorily after a 5-minute exposure 3 m (10 ft) above a 4.65-m^2 (50-ft^2) N-heptane fire using 379 L (100 gal) of fuel. The test fire should be shielded to ensure flame impingement on the generator.

A.8.11.1.1 Galvanizing is not compatible with some foam concentrates.

A.8.12.2.2 See NFPA 13, *Standard for the Installation of Sprinkler Systems.*

A.8.13.4 *Submergence Time — Vulnerability of Structure.* It is imperative that the integrity of primary structural members be maintained under fire exposure (which, in sprinklered structures, normally support the sprinkler system). Light, unprotected bar joist and other similar types of supports are especially vulnerable to damage by fast-developing fires as compared to that of heavy steel construction. So also is heavy, unprotected steel framing more vulnerable than fire-resistive (concrete) or protected structural members.

A.8.13.5 Tests with foams of above 400:1 expansion ratio have shown that extinguishment times for flammable liquid fires increased significantly at rates of foam rise less than 0.9 m/min (3 ft/min). It is expected that at some expansion ratio below 400:1, lower rates of foam rise would be adequate, but insufficient tests have been conducted to identify this ratio.

A.8.13.5.2.1 The rate also depends on foam properties, such as expansion ratio, water retention, effect of water contaminants, and temperature effects on water retention.

A.8.13.5.2.2(1) *Sample Calculation of Total High-Expansion Foam Generator Capacity.*

(1) *Calculation Using U.S. Units.*

Given: Building size — 100 ft × 200 ft × 30 ft high.

Building construction — Light bar joist, Class I steel deck roof, adequately vented. Masonry walls with all openings closable.

Sprinkler protection — Wet system 10 ft × 10 ft spacing. 0.25 gpm/ft^2 density.

Occupancy — Vertically stacked unbanded rolled kraft paper 25 ft high.

Assume: Fire will open 50 sprinkler heads. Foam leakage around closed doors, drains, and so forth, hence $C_L = 1.2$.

Calculation:

Foam Depth

Depth = 25 × 1.1 = 27.5 ft

(This depth is greater than minimum cover of 2 ft.)

Submergence Volume

$V = 100 \times 200 \times 27.5 = 550{,}000$ ft^3

Submergence Time

$T = 5$ minutes (from Table 8.13.4)

Rate of Foam Breakdown by Sprinklers

$S = 10$ ft^3/min · gpm [from 8.13.5.2.2(2)]

Q = Number of heads × area/head × density = 50 × (10 × 10) × 0.25 = 1250 gpm

$R_S = S \times Q = 10 \times 1250 = 12{,}500$ ft^3/min

Normal Foam Shrinkage

$C_N = 1.15$ [from 8.13.5.2.2(3)]

Leakage

$C_L = 1.2$ (assumption)

Total Generator Capacity

$$R = \left(\frac{V}{T} + R_S\right) \times C_N \times C_L$$

$$R = \left(\frac{550{,}000}{5} + 12{,}500\right) \times 1.15 \times 1.2$$

$R = 169{,}000$ ft^3/min

The number of generators required will depend upon the capacity of the generators available.

(2) *Calculation Using SI Units.*

Given: Building size — 30.5 m × 61 m × 9.1 m high.

Building construction — Same as U.S. units calculation.

Sprinkler protection — Wet system 3 m × 3 m spacing. 10.2 L/min · m^2 density.

Occupancy — Vertically stacked unbanded rolled kraft paper 7.6 m high.

Assume: Same assumption as U.S. units calculation.

Calculation:

Foam Depth

Depth = 7.6 × 1.1 = 8.4 m

(This depth is greater than minimum cover of 0.6 m.)

Submergence Volume

$V = 30.5 \times 61 \times 8.4 = 15{,}628$ m^3

Submergence Time

$T = 5$ minutes (from Table 8.13.4)

Rate of Foam Breakdown by Sprinklers

$S = 0.0748$ m^3/min · L/min [from 8.13.5.2.2(2)]

Q = Number of heads × area/head × density = 50 × (3 × 3) × 10.2 = 4590 L/min

$R_S = S \times Q = 0.0748 \times 4590 = 343$ m^3/min

Normal Foam Shrinkage

$C_N = 1.15$ [from 8.13.5.2.2(3)]

Leakage

$C_L = 1.2$ (assumption)

Total Generator Capacity

$$R = \left(\frac{V}{T} + R_S\right) \times C_N \times C_L$$

$$R = \left(\frac{15{,}628}{5} + 343\right) \times 1.15 \times 1.2$$

$R = 4787$ m^3/min

A.8.13.5.2.2(2) *Rate of Breakdown by Sprinklers.* Where sprinklers are present in an area to be protected by high-expansion foam, simultaneous operation will cause breakdown of the foam. The rate of breakdown will depend on the number of sprinklers operating and the subsequent total rate of water discharge. The number of sprinklers expected to operate will depend on various factors as outlined in NFPA 13, *Standard for the Installation of Sprinkler Systems*.

A.8.13.5.2.2(4) *Foam Leakage.* It is essential that uncontrolled leakage be reduced to an absolute minimum through the use of foamtight barriers at all openings below the effective hazard control level or depth. There will be an increased rate of foam escape as its fluidity is increased by anticipated sprinkler discharge.

Such leakage through drains, trenches, under doors, around windows, and so forth can be minimized by use of suitable automatic closures, seals, or mechanisms. Additional generator capacity should be added to compensate for the aggregate losses where foam escapement cannot be effectively controlled.

A.8.14 *Maintenance of Submergence Volume.* The choice of a total flooding foam system for protection of a hazard does not necessarily imply that it is expected that the system will completely extinguish the fire or even so nearly extinguish it as to render the fire incapable of regaining the offensive. Rather, the effect sought might often be speedy control with minimum fire damage to contents not involved in the fire.

When high-expansion foam is establishing or has established control of a fire, care must be exercised that control is not lost. The following points should be kept in mind; depending on the particular fire, some or all might be vital:

(1) All persons should be aware of the necessity for tight closure. Employees, brigade members, and the fire department should move rapidly to close any openings through which foam is being lost. Improvised closures can be made of practically any available material such as fine mesh screening, plastic, plywood, or cardboard.
(2) If the material involved is liable to sustain deep-seated fires, such as furniture, packaged material, fibers, and rolls of paper, particular care must be exercised in opening up the areas and removing the foam. Even where only surface fire is thought possible, as in flammable liquids, smoldering Class A material can cause reignition.
(3) A "soaking" period should elapse before foam is removed. This period can be as long as an hour and should be predetermined based on the fuel in the area.

A.8.15 The following points should be considered during overhaul operations:

(1) All foam and sprinkler systems that are shut off should have personnel standing by valves to turn them back on if this should become necessary.
(2) Foam supplies should be replenished if depleted.
(3) Hand hoselines should be charged and manned. Personal protective equipment should be donned. Self-contained breathing apparatus must be worn in the "ready" position so there will be no delay in putting it in service.
(4) Foam should be removed first from the fire area and should be coordinated with overhaul and salvage operations. The total loss will be kept to a minimum if thoughtless operations are avoided. Once the fire is under control, undue haste to extinguish the last ember can greatly increase the loss.
(5) Caution should be taken in entering previously foam-filled areas, particularly in structures with pits or openings in the floor.
(6) The area should be well ventilated, but openings through which foam might be lost should be kept to a minimum and manned for closing if this should become necessary.
(7) Consideration should be given to disposal of the foam to prevent any undue hazard to adjacent areas.

A.8.17.1.2 These systems are best adapted to the protection of essentially flat surfaces such as confined spills, open tanks, drainboards, curbed areas, pits, trenches, and so forth.

A.8.18.2 Fences constructed of ordinary metal window screen mesh have been shown to provide an effective barrier that allows confinement of medium- and high-expansion foam to a protected area.

A.8.20 Special provisions for liquefied natural gas (LNG) fire and vapor control are as follows:

(1) *Application Concepts for Fire Control.* Tests sponsored by the American Gas Association (AGA) have shown that the amount of radiation from a burning LNG spill can be reduced by as much as 95 percent with some high-expansion foams. This reduction is due in part to the foam barrier, which reduces vaporization by blocking heat feedback from the flames to the LNG. Foams having a low-expansion ratio contain a great deal of water at ambient temperature that tends to increase the vaporization rate when it drains into the LNG. In the AGA tests, control was established with expansion ratios greater than 250:1, although an expansion ratio of about 500:1 proved most effective. Different brands of foam show considerable variation in their ability to control LNG fires. A rapidly draining foam will increase the LNG vaporization rate and exaggerate the fire intensity. The drier foam remaining is less resistant to thermal effects and breaks down more readily. Other factors such as bubble size, fluidity, and linear burn rate can affect fire control. Therefore, test results on LNG fires, including the test described in G.4 should be reviewed before selecting a foam for LNG fire control.
(2) *Downwind Vapor Hazard Control.* When first evolved from a spill, unignited LNG vapors are heavier than air. As these vapors are heated by sunlight or by contact with the air, they eventually become buoyant and disperse upward. Before this upward dispersal occurs, however, high vapor concentrations can form downwind of an unignited spill at or near ground level. High-expansion foam can be used to reduce this vapor concentration by adding heat from the water in the foam to the LNG vapors as they pass through the foam blanket. Because of the induced buoyancy, the application of high-expansion foam can reduce downwind gas concentrations at ground level. Expansions in the range of 750:1 to 1000:1 have been found to provide the most effective dispersion control, but the higher expansions can be adversely affected by wind. However, as with fire control, ability to control vapor dispersion varies among different foams and should be demonstrated by tests.

A.8.20.1 See NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, for information on fire protection requirements for LNG facilities.

A.8.20.2 LNG fire and vapor control reference publications are as follows:

(1) American Gas Association Project IS-3-1, "LNG Spills on Land," November 15, 1973.
(2) American Gas Association Project IS-100-1, "An Experimental Study on the Mitigation of Flammable Vapor Dispersion and Fire Hazards Immediately Following LNG Spills on Land," February 1974.

(3) Gremeles, A. E., and Drake, E. M., "Gravity Spreading and Atmospheric Dispersion of LNG Vapor Clouds," Fourth International Symposium on Transport of Hazardous Cargoes by Sea and Inland Waterways, Jacksonville, FL, October 1975.
(4) Humbert-Basset, R. and Montet, A., "Flammable Mixture Penetration in the Atmosphere from Spillage of LNG," Third International Conference on LNG, Washington, DC, September 1972.
(5) "Liquefied Natural Gas/Characteristics and Burning Behavior," Conch Methane Services, Ltd., 1962.
(6) "LNG Vapor Concentration Reduction and Fire Control with MSAR High Expansion Foam," Mine Safety Appliances Research Corp., Evans City, PA.
(7) Schneider, Alan L., "Liquefied Natural Gas Safety Research Overview," National Technical Information Service, Springfield, VA, December 1978.
(8) Welker, J., et al., "Fire Safety Aboard LNG Vessels." January 1976.
(9) Wesson, H. R., Welker, J. R., and Brown, L. E., "Control LNG Spill Fires," *Hydrocarbon Processing*, December 1972. This paper contains 105 additional references on many aspects of LNG safety research including the use of high-expansion foam on LNG.

A.8.20.3 Application rates are generally established by specific fire tests such as that in G.4 where the equipment, water supply, fuel, and physical and chemical makeup of the candidate foam concentrate are carefully controlled. While these tests can be useful for comparing various foams, they often give minimum application rates because they are conducted under ideal weather conditions with no obstructions or barriers to fire control. The final design rates are generally 3 to 5 times the test rates. Thus, the rates can very significantly from one foam agent to another.

A.8.20.5 *Arrangement.* The minimum foam depth at any point in the hazard area will vary, but most designs have attempted to obtain 0.45 m to 1.5 m (1½ ft to 3 ft) of foam depth over the LNG spill area within the time established in the analysis.

A.8.21.6.1 Successful extinguishment of fire with portable foam-generating devices is dependent on the individual ability and technique of the operator.

A.9.1 The provisions of this marine chapter were developed based on knowledge of practices of NFPA 11, *Standard for Low-Expansion Foam*, SOLAS, the IBC Code, and USCG regulations and guidance. In order to harmonize the requirements of this chapter with the practices of these other standards, the values given in the metric conversions in Chapter 10 should be considered the required value.

A.9.1.3 Approvals of specialized foam equipment components are typically based on compliance with a standard equivalent to UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates*. Component review should include the following:

(1) Fire suppression effectiveness
(2) Reliability
(3) Mechanical strength
(4) Corrosion resistance
(5) Material compatibility
(6) Proper operation
(7) Stress, shock, and impact
(8) Exposure to salt water, sunlight, temperature extremes, and other environmental elements
(9) Proportioning system test data (demonstrating acceptable injection rate over the intended flow range of the system)
(10) Foam stream range data (based on still air testing with monitor and nozzle combinations)
(11) Foam quality test data (demonstrating satisfactory performance corresponding to small scale fire test nozzle foam quality)

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

A.9.1.4.3 Foams for polar solvents are first tested for hydrocarbon performance using a test derived from Federal Specification O-F-555C that was published from 1969 through 1990. The foams are further tested for polar solvent system application on the basis of 4.6 m^2 (50 ft^2) fire test performance in accordance with UL 162, *Standard for Safety Foam Equipment and Liquid Concentrates*. Approved manufacturers' deck system design application rates and operating times incorporate design factors that are applied to the fire test application rates and times.

A.9.2.1 This system is intended to supplement, not replace, any required total flooding machinery space fire suppression system. Foam systems comprising a portion of required primary machinery space protection can require longer application times.

A.9.3.1 Although shipboard foam systems share many similarities with tank farm foam systems on land, there are important differences between shipboard and land-based fire protection. These differences, identified in (1) through (15), result in foam system designs and arrangements that differ from systems used in what can appear to be similar land-based hazards. The differences are as follow:

(1) Foam fire tests of the type described in Annex F are very severe.
(2) There is limited data regarding use of systems meeting USCG or IMO requirements on actual fires.
(3) There is little or no separation between tanks.
(4) The vessel might be widely separated from other hazards or might be alongside another vessel or a terminal.
(5) The vessel might not have access to immediate fire-fighting assistance.
(6) Fires resulting from catastrophic events, such as explosions and collisions, historically are beyond the onboard fire-fighting capabilities of the involved vessels, necessitating use of outside fire-fighting assistance. Many large fires have taken several days to extinguish.
(7) The number of fire-fighting personnel is limited to the available crew.
(8) Fires not substantially controlled within the first 20 minutes can exceed the capability of the crew and the onboard system.
(9) Ships are subject to rolling, pitching, and yawing, which can cause sloshing of the burning liquid and reduced performance of the foam blanket.

(10) Application of foam to the fire is likely to be much faster than on land because the deck foam system is in place and can be activated simply by starting a pump and opening certain valves. There is little or no set-up time.
(11) Tank fires don't seem to occur unless preceded by an explosion.
(12) Explosions can cause substantial damage to foam systems. They can have unpredictable results on the vessel structure including bending deck plating in such a way so as to obstruct foam application. They can also cause involvement of any number of tanks or spaces.
(13) Most tankers use inert gas systems to reduce vapor spaces above cargo tanks to less than 8 percent oxygen thereby reducing the likelihood of an explosion.
(14) Ships pay the cost of transporting their fire suppression systems on every voyage.
(15) There is a finite amount of space on each ship design. Tanker deck foam monitors are located at or above the elevation of top of the tank as contrasted with typical tank farm arrangements where monitors must project foam up and over the rim of a tank.

A.9.3.2.2 Color coding the valves aids in identification. For example, all valves that are to be opened might be painted some distinctive color.

A.9.3.3 A fire main system can provide other services in addition to fire protection. Other services, which could be left operational during a fire, need to be included in calculations.

A.9.3.4 Rates of application are as follows:

(1) *Differences Between this Section and SOLAS or the IBC Code.* The application rates prescribed in this section for hydrocarbon fuels are higher than the rates given in the International Maritime Organization's International Convention for the Safety of Life at Sea (SOLAS) Chapter 212, Regulation 61, as follows:
   (a) *Deck spills.* This section requires 6.5 L/min·m^2 (0.16 gpm/ft^2) applied over the 10 percent of the cargo block versus 5.98 L/min·m^2 (0.147 gpm/ft^2) in SOLAS. This difference is based on a long history of fire extinguishment experience using 6.5 L/min·m^2 (0.16 gpm/ft^2). It is also understood that the value 6.5 L/min·m^2 (0.16 gpm/ft^2) is generally regarded as the minimum foam application rate for industrial hazards and reflects the minimum application rate on the fuel surface, not at the discharge device. Thus, loss of foam due to wind, obstructions, and so forth, should be compensated for to provide 6.5 L/min·m^2 (0.16 gpm/ft^2) on the liquid surface.
   (b) *Single largest tank.* This section requires 9.77 L/min·m^2 (0.24 gpm/ft^2) over the single largest hydrocarbon tank versus 5.98 L/min·m^2 (0.147 gpm/ft^2) in SOLAS. This difference is based on the need to deliver a minimum of 6.5 L/min·m^2 (0.16 gpm/ft^2) onto the surface of the burning fuel and takes into consideration the impact of wind, evaporation, and thermal updrafts. This value is consistent with recent experience with the extinguishment of shore-based storage tanks using mobile foam equipment similar to the monitors used in deck foam systems.
   (c) *Polar solvents.* The *International Bulk Chemical Code* (IBC Code) provides two design methods. The first method requires a foam application rate of 20.3 L/min·m^2 (0.5 gpm/ft^2) without restriction to the type of chemicals that can be carried or where on the ship's cargo block they can be carried. The second method allows arrangements with application rates lower than 20.3 L/min·m^2 (0.5 gpm/ft^2). This method is allowed if the country where the vessel is registered has determined through fire tests that the actual foam application rate at each cargo tank is adequate for the chemicals carried in that tank. The design practices given in this section comply with the second method of the *IBC Code. (Reference 1994 IBC Code Regulation 11.3.13.)*
(2) *Reliance on Monitor Application.* It is recognized that for land applications this standard generally restricts monitor application of foam according to tank diameter and surface area. A significant difference between monitor applications on land and those on tank ships is that the monitors on tank ships are located at or above the elevation of the top of the tank. Therefore, shipboard systems do not suffer losses of agent associated with long throws getting foam up and over tank rims. Additionally, tank ship monitors can be placed in operation immediately after an incident as there is little or no set-up time and each monitor is required to be sized to deliver at least 50 percent of the required foam application rate.
(3) *Design Factors.* The application rates given in this section incorporate design factors that allow the results of small-scale fire tests to be applied to full-scale fires. Design factors include scaling factors that allow the results of small-scale tests to be extrapolated to large scale. In addition, compensation factors are included to account for losses expected from wind, thermal updraft, stream break-up, plunging, and other adverse conditions. The application rates and incorporated design factors are shown in Table A.9.3.4.
(4) *Monitor Design Philosophy.* The design philosophy given in this standard reflects that outlined in NVIC 11-82, *Deck Foam Systems for Polar Solvents.* NVIC 11-82 assumes that the minimum single tank design application rate will be 6.5 L/min·m^2 (0.16 gpm/ft^2). It then allows monitors to be calculated using 45 percent of the single tank rate. SOLAS and the *IBC Code* require the monitor to be calculated at 50 percent of the single tank rate. However, SOLAS starts with a single tank application rate of 6 L/min·m^2 (0.147 gpm/ft^2) so that 50 percent of that rate exactly equals 3 L/min·m^2 (0.0735 gpm/ft^2), which is 45 percent of the NVIC 11-82 minimum application rate of 6.5 L/min·m^2 (0.16 gpm/ft^2). The *IBC Code* also requires monitors to be sized for 50 percent of the single tank flow rate.

A.9.3.5.1 Foam application durations given in this section are generally lower than those given in other sections of this standard. This difference is based on historically quick deployment of marine deck foam systems and also takes into account all of the factors listed in A.9.3.1.

A.9.3.5.3 The flow rates during an actual system discharge will generally be greater than the minimum rates calculated during system design because pumps, eductors, and nozzles are typically not available in sizes for the exact minimum flow rate needed. Therefore, this equipment will typically be selected at the next larger commercially available size. Because the system, built of components larger than the minimum required, will flow foam at a rate greater than the minimum calculated, the foam concentrate will be used faster than the minimum usage rate. Since the concentrate will be used at a

Table A.9.3.4 Foam Application Rates

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

rate higher than the minimum, the storage quantity should be sized to provide the actual delivery rate during the entire required discharge duration.

A.9.4 Although foam handlines are required for supplementary protection, it is not practical to rely on handlines for primary fire fighting. Therefore, all required foam application must be provided by monitors that cover the protected area.

A.9.9.2 Pipe should be uniformly supported to prevent movement due to gravity, heaving of the vessel in heavy weather, impact, and water hammer. Pipe should be supported by steel members.

A.9.9.3 Deck foam system piping is not a substitute for any portion of a vessel's fire main system. Conversely, the requirement is intended to clarify that foam injected into the ship's fire main is not a substitute for a dedicated foam system on the weather deck. The requirement is not intended to prevent the proportioning of foam into a ship's fire main. Such a capability may be of great value during a machinery space fire or any other fire involving flammable liquids.

A.9.9.4 The system should be arranged to prevent ice from forming in any portion of the system. Sloped piping and manual low point drains are considered to meet the requirement that the system be self-draining.

A.9.10.1 Refer to the environmental report (Annex E) for further information related to environmental issues when performing system discharge tests.

A.9.11.1.1 The primary foam concentrate tank is the tank containing the supply calculated to satisfy the requirements of 9.3.4 and 9.3.5. The location of emergency back-up supplies and supplies of concentrate for refilling the primary tank are not subject to the storage location restrictions of 9.11.2. However, all foam concentrate storage is subject to other provisions of this chapter such as those regarding prevention of freezing and foam compatibility.

A.9.11.2.1 Corrosion occurs at the air/foam/tank interface. Therefore, the small surface area of this interface in the tank dome results in less corrosion than if the interface occurs in the body of the tank. Tank domes are also used to reduce the available free surface subject to sloshing. Sloshing causes premature foaming and adversely affects foam proportioning. In addition, sloshing can cause cracking or other damage to the tank. Also foam evaporates so the use of a pressure vacuum (PV) vent is necessary. A PV vent allows air to enter the tank as liquid is discharged, allows air to leave the tank as liquid fills the tank, and allows the PV valve to prevent evaporation of the concentrate.

A.9.12.1 Examples of acceptable arrangements are shown in Figure A.3.3.24.4(a) and Figure A.3.3.24.4(b). Consideration should be given to the need for spare or redundant critical equipment.

A.9.12.2 Where foam concentrate pumps are flushed with sea water, the pump should be constructed of materials suitable for use with sea water.

A.9.12.3 Portions of TP 127 are generally considered equivalent to IEEE 45, *Recommended Practice for Electrical Installations on Shipboard.*

A.9.13.5 Some pipe joint sealants are soluble in foam concentrate.

A.10.3 Acceptance tests should be as follows:

(1) A foam system will extinguish a flammable liquid fire if operated within the proper ranges of solution pressure and concentration and at sufficient discharge density per square feet (square meters) of protected surface. The acceptance test of a foam system should ascertain the following:
   (a) All foam-producing devices are operating at system design pressure and at system design foam solution concentration.
   (b) Laboratory-type tests have been conducted, where necessary, to determine that water quality and foam liquid are compatible.
(2) The following data are considered essential to the evaluation of foam system performance:
   (a) Static water pressure
   (b) Stabilized flowing water pressure at both the control valve and a remote reference point in the system
   (c) Rate of consumption of foam concentrate

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

A.10.6 The rate of concentrate consumption can be measured by timing a given displacement from the foam concentrate storage tank but only in systems where the storage tank is small enough and the test run time is long enough so that this can be accomplished with reasonable accuracy.

A.10.6.3(2) The rate of concentrate flow can be measured by timing a given displacement from the storage tank. Solution concentration can be measured by either refractometric or conductivity means *(see Section C.2)*, or it can be calculated from solution and concentrate flow rates. Solution flow rates can be calculated by utilizing recorded inlet or end-of-system operating pressures or both.

A.11.1 Flushing of the concentrate pump might be necessary at periodic intervals or following complete discharge of concentrate.

A.11.2 Regular service contracts are recommended.

Annex B Storage Tank Protection Summary

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

B.1 See Table B.1.

Table B.1 Storage Tank Protection Summary

	Fixed-Roof (Cone) Tanks and Pan-Type Floating Roof Tanks			Applicable Floating Roof Tanks (Open-Top or Covered) Annular Seal Area
Top Side Foam Application				
Number of foam outlets required	Up to 24.4 m (80 ft) dia.	1 foam chamber		1 for each 12.2 m (40 ft) of circumference with a 304.8 mm (12 in.) high foam dam
	24.7 to 36.6 m (81 to 120 ft) dia.	2 foam chambers		
	36.9 to 42.7 m (121 to 140 ft) dia.	3 foam chambers		1 for each 24.4 m (80 ft) of circumference with a 609.6 mm (24 in. high foam dam)
	43 to 48.8 m (141 to 160 ft) dia.	4 foam chambers		
	49.1 to 54.9 m (161 to 180 ft) dia.	5 foam chambers		*(See 5.3.3.1 and Section 5.4.)*
	55.2 to 61 m (181 to 200 ft) dia.	6 foam chambers		
	Over 61.3 m (201 ft) dia.	1 additional for each 465 m^2 (5000 ft^2)		
	(See Table 5.2.4.2.1.)			
Hydrocarbon application rates	4.1 L/min·m^2 (0.10 gpm/ft^2) of liquid surface *(See Table 5.2.4.2.2.)*			12.2 L/min·m^2 (0.30 gpm/ft^2) of annular ring area, above seal, between tank wall and foam dam *(See Section 5.3.)*
Polar solvent rates	See Manufacturer's Approval Report.			Not covered by NFPA 11
Hydrocarbon discharge times				
		Type I	Type II	
	Flash point 37.8°C to 60°C (100°F to 140°F)	20 min	30 min	20 min
	Flash point below 37.8°C (100°F)	30 min	55 min	
	Crude petroleum	30 min	55 min	*(See Section 5.3.)*
Polar solvents	Type I	30 min		Not covered by NFPA 11
	Type II	55 min		

Table B.1 ***Continued***

	Fixed-Roof (Cone) Tanks and Pan-Type Floating Roof Tanks		Applicable Floating Roof Tanks (Open-Top or Covered) Annular Seal Area
Foam Outlets Under Floating Roof Tank Seals or Metal Secondary Seal			
Number required	Not applicable		Mechanical shoe seal 1 — For each 39.6 m (130 ft) of tank circumference (no foam dam required) Tube seal—Over 152 mm (6 in.) from top of seal to top of pontoon with foam outlets under metal weather shield or secondary seal 1 — For each 18.3 m (60 ft) of tank circumference (no foam dam required) Tube seal — Less than 152 mm (6 in.) from top of seal to top of pontoon with foam outlets under metal weather shield or secondary seal 1 — For each 18.3 m (60 ft) of tank circumference [foam dam at least 305 mm (12 in.) high required] *(See 5.3.5.4.)*
Hydrocarbon application rates	Not applicable		Top-of-seal protection with foam dam at 12.2 L/min·m^2 (0.30 gpm/ft^2) of annular ring area. All below-the-seal with or without foam dam at 20.4 L/min·m^2 (0.50 gpm/ft^2)
Discharge times	Not applicable		20 min — with foam dam or under metal weather shield or secondary seal
Polar solvents	Not applicable		Not covered by NFPA 11
Foam Handlines and Monitors for Tank Protection			
Size of tank	Monitors for tanks up to 18.3 m (60 ft) in diameter Hand hoselines for tanks less than 9.2 m (30 ft) in diameter and less than 6.1 m (20 ft) high *(See 5.2.2.1.)*		Monitors not recommended Handlines are suitable for extinguishment of rim fires in open-top floating roof tanks *(See 5.3.4.)*
Hydrocarbon application rates	6.5 L/min·m^2 (0.16 gpm/ft^2) *(See 5.2.2.2, 5.2.2.3, and 5.2.2.4.)*		6.5 L/min·m^2 (0.16 gpm/ft^2) For rim fires in open-top floating roof tanks *(See 5.2.2.2, 5.2.2.3, and 5.2.2.4.)*
Discharge times	Flash point below 37.8°C (100°F)	65 min	Use same times as for open-top floating roof tank rim fires
	Flash point 37.8°C to 60°C (100°F to 140°F)	50 min	
	Crude oil *(See 5.2.2.3.)*	65 min	

Table B.1 *Continued*

	Fixed-Roof (Cone) Tanks and Pan-Type Floating Roof Tanks		Applicable Floating Roof Tanks (Open-Top or Covered) Annular Seal Area
Subsurface Application Outlets			
Number required	Same as table for foam chambers. See above. *(See 5.2.4.1, 5.2.4.2, and 5.2.4.2.1.)*		Not recommended
Hydrocarbon application rates	Minimum 4.1 L/min·m^2 (0.1 gpm/ft^2) of liquid surface Maximum 8.2 L/min·m^2 (0.2 gpm/ft^2) Foam velocity from outlet shall not exceed 3.05 m /sec (10 ft/sec) for Class IB liquids or 6.1 m/sec (20 ft/sec) for all other liquids *(See 5.2.4.2 and 5.2.4.3.)*		Not recommended
Discharge times	Flash point 37.8°C (100°F) to 60°C (140°F)	30 min	Not recommended
	Flash point below 37.8°C (100°F)	55 min	
	Crude petroleum *(See 5.2.4.3.)*	55 min	
Polar solvents	Not recommended		Not recommended

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

Annex C Tests for the Physical Properties of Foam

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

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

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

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

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

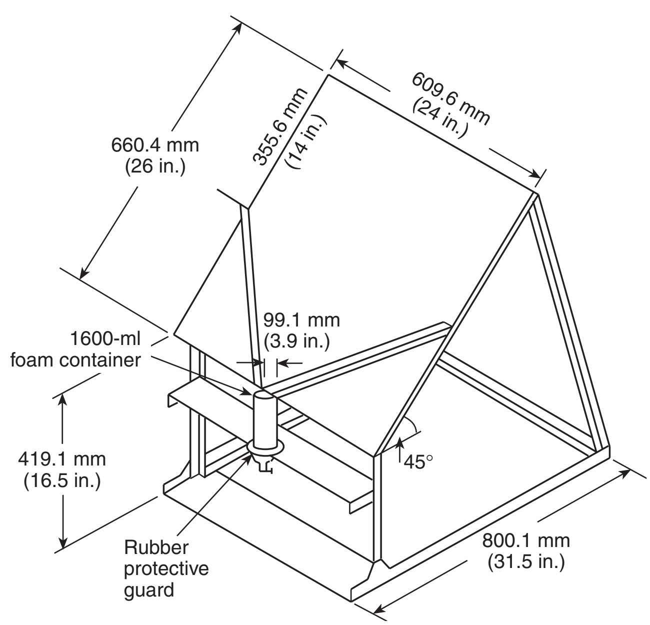

FIGURE C.1.1(a) Foam Sample Collector.

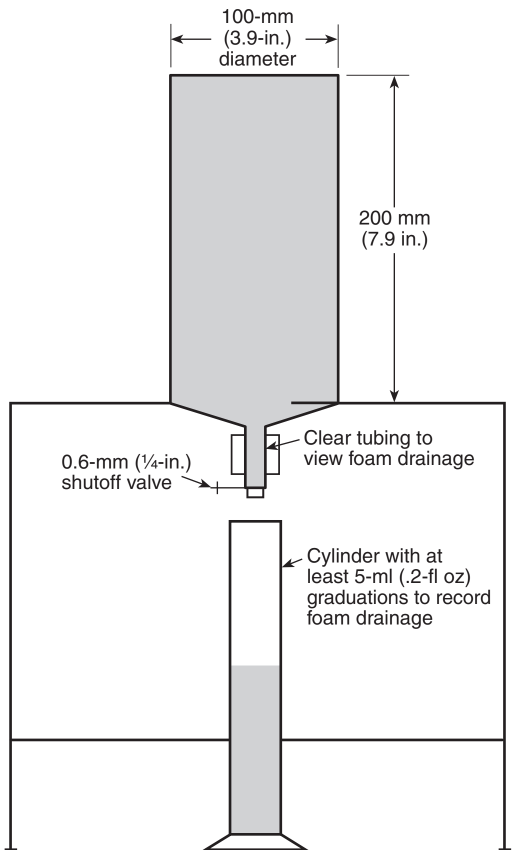

FIGURE C.1.1(b) 1600-ml Foam Container.

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

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

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

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

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

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

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

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

The following apparatus is required:

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