ANSI/NFPA 11 An American National Standard December 2, 1987

NFPA 11
Low Expansion Foam and Combined Agent Systems
1988 Edition

NFPA

National Fire Protection Association Batterymarch Park, Quincy, MA 02269

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The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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NFPA 11

Standard for

Low Expansion Foam and Combined Agent Systems

1988 Edition

This edition of NFPA 11, *Standard for Low Expansion Foam and Combined Agent Systems*, was prepared by the Technical Committee on Foam, and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 9-11, 1987 in Portland, Oregon. It was issued by the Standards Council on December 2, 1987, with an effective date of December 22, 1987, and supersedes all previous editions.

The 1988 edition of this standard has been approved by the American National Standards Institute.

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

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*. A new format was used to be consistent with that used in the international foam systems standard. The standard was revised in 1988.

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

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Foreword

Foam for fire protection purposes is an aggregate of air-filled bubbles formed from aqueous solutions and is lower in density than the lightest flammable liquids. It is principally used to form a coherent floating blanket on flammable and combustible liquids lighter than water and prevents or extinguishes fire by excluding air and cooling the fuel. It also prevents reignition by suppressing formation of flammable vapors. It has the property of adhering to surfaces, providing a degree of exposure protection from adjacent fires.

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

Foam may be supplied by overhead piped systems for protection of hazardous occupancies involving potential flammable liquid spills in the proximity of high-value equipment, or in large areas. The application of foam for this type of hazard 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 spaced to cover the entire area at a uniform density. This standard covers requirements for foam spray systems. For systems required to meet both foam and water spray design criteria, refer to NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler and Foam-Water Spray Systems.*

Large spill fires of flammable liquids can be fought with mobile equipment, such as an airport 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 may be delivered as a solid stream or in a dispersed pattern. Standards for industrial foam trucks will be found in NFPA 11C, *Standard for Mobile Foam Apparatus*, and standards for aircraft crash trucks will be found in NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles.*

While other extinguishing agents are also recognized for use on flammable liquid fires, it should be noted that for flammable liquid fires in large storage tanks, only foam has been found to be practical to obtain extinguishment.

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

Foam may also be used for heat radiation protection. Foam reduces heat transmission to solid surfaces on which it has been applied because of its insulating characteristics, cooling effect, and reflectivity. In the case of solid combustible surfaces, these characteristics may prevent ignition.

Chapter 1 General Information

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

Information on referenced publications can be found in Chapter 7 and Appendix D.

1-1 Scope. This standard covers the characteristics of foam-producing materials used for fire protection and the requirements for design, installation, operation, testing, and maintenance of equipment and systems, including those used in combination with other fire extinguishing agents. Minimum requirements are covered for flammable and combustible liquid hazards in local areas within buildings, for storage tanks, and for indoor and outdoor processing areas.

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

This standard does not include requirements for medium or high expansion foam systems, which are covered in NFPA 11A, *Standard for Medium and High Expansion Foam Systems.*

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

1-3 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). One unit (liter), outside of but recognized by SI, is commonly used in international fire protection. The units are listed in Table 1-3 with conversion factors.

1-3.1 If a value or measurement given in this standard is followed by an equivalent value in SI units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

Table 1-3

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 3.785 L
liter per minute per square meter	(L/min) m²	1 gpm/ft² = 40.746 (L/min)/m²
cubic decimeter	dm³	1 gal = 3.785 dm³
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

For additional conversions and information see ASTM E380, *Standard for Metric Practice*. (*See Appendix C.*)

1-4* Definitions.

Approved. Acceptable to the "authority having jurisdiction."

NOTE: 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 or 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 concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, 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 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."

Concentration. The percent of foam concentrate contained in a foam solution. The type of foam concentrate being used determines the percentage of concentration required. A 3 percent foam concentrate is mixed in the ratio of 97 parts water to 3 parts foam concentrate to make foam solution. A 6 percent concentrate is mixed with 94 parts water to 6 parts foam concentrate.

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

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

Expansion. The ratio of final foam volume to original foam solution volume before adding air.

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

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

1. Class IA liquids shall include those having flash points below 73°F (22.8°C) and having a boiling point below 100°F (37.8°C).

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

3. Class IC liquids shall include those having flash points at or above 73°F (22.8°C) and below 100°F (37.8°C).

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

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

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

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

Foam. Fire fighting foam, within the scope of this standard, is a stable aggregation of small bubbles of lower density than oil or water, and shows tenacious qualities 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 to seal 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 are also 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: low expansion foam — expansion up to 20; medium expansion foam — expansion 20-200; and high expansion foam — expansion 200-1000.

Foam Concentrate. Foam concentrate is a concentrated liquid foaming agent as received from the manufacturer.

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

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

(c) **Synthetic Foam Concentrates** — based on foaming agents other than hydrolysed proteins. They include:

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

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

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

(d) **Film-Forming Fluoroprotein (FFFP) Foam Concentrates** — use fluorinated surfactants to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors. This type of foam also 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 or 6 percent solution and is dry chemical compatible.

(e) **Alcohol-Resistant Foam Concentrates** — used for fighting fires on water-soluble materials and other fuels destructive to regular, AFFF, or FFFP foams, as well as 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. Another 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 may also have film-forming characteristics on hydrocarbon fuels. The third is based on both water-soluble natural polymers, such as fluoroprotein, and contain a gelling agent that protects the foam from water-soluble fuels. This foam may 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.

(f) **Compatibility of Concentrates and Their Foams** — Different types and brands of concentrates may be incompatible and shall not be mixed in storage. Foams generated separately from protein, fluoroprotein, FFFP, and AFFF concentrates may be applied to a fire in sequence or simultaneously.

(g) **Chemical Foam** — made by the reaction of an alkaline salt solution (usually bicarbonate of soda) and an acid salt solution (usually aluminum sulfate) to form a gas (carbon dioxide) in the presence of a foaming agent that causes the gas to be trapped in bubbles to form a tough, fire-resistant foam.

NOTE: This type of foam is considered obsolete and has generally been replaced by air foam.

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

Foam Nozzles or Fixed Foam Makers. A specially designed hose line nozzle or fixed foam maker designed to aspirate air is connected to a supply of foam solution. They are so constructed 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 may be installed at the end of the nozzle to cause the foam to issue in a wide pattern or a compacted stream.

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 may be conducted through piping or hoses to the hazard being protected.

Foam Solution. Foam solution is a homogeneous mixture of water and foam concentrate in the proper proportions.

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

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

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

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

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

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.

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.

In-Line Eductor. A Venturi eductor is located in the water supply line to the foam maker. This is connected by single or multiple lines to the source of foam concentrate. It is precalibrated and it may be adjustable.

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 may 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.

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.

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.

Shall. Indicates a mandatory requirement.

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

Unstable (Reactive) Liquid. A liquid that will vigorously polymerize, decompose, condense, or will become self-reactive under certain conditions of shock, pressure, or temperature.

Chapter 2 Foam Systems — Types and Requirements

2-1 System Description.

2-1.1 A system consists of an adequate water supply, a supply of foam concentrate, suitable proportioning equipment, a proper piping system, foam makers, and discharge devices designed to adequately distribute the foam over the hazard. Some systems may include detection devices.

2-1.2 These systems are of the open outlet type in which foam discharges from all outlets at the same time, covering the entire hazard within the confines of the system.

2-1.3 Self-contained systems are those in which all components and ingredients, including water, are contained within the system. Such systems usually have a water supply or premix solution supply tank pressurized by air or inert gas. The release of this pressure places the system into operation.

2-1.4 There are four basic types of systems:

(a) Fixed

(b) Semifixed

(c) Mobile

(d) Portable.

2-1.4.1 Fixed Systems. These are complete installations piped from a central foam station, discharging through fixed delivery outlets to the hazard to be protected. Any required pumps are permanently installed.

2-1.4.2 Semifixed Systems.

(a) 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 may or may not include a foam maker. Necessary foam-producing materials are transported to the scene after the fire starts and are connected to the piping.

(b) The type in which foam solutions are piped through the area from a central foam station, the solution being delivered through hose lines to portable foam makers, such as monitors, foam towers, hose lines, etc.

2-1.4.3 Mobile Systems. This includes any foam-producing unit that is mounted on wheels, and that may be self-propelled or towed by a vehicle. These units may be connected to a suitable water supply or may utilize a premixed foam solution. For mobile systems, refer to NFPA 11C, *Standard for Mobile Foam Apparatus*.

2-1.4.4 Portable Systems. The type in which the foam-producing equipment and materials, hose, etc., are transported by hand.

2-2 Water Supplies.

2-2.1 Water Supplies, Including Premix Solution.

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

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

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

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

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

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

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

2-3 Foam Concentrate, Supplies, and Pumps.

2-3.1 Storage.

2-3.1.1 Storage Facilities. Foam concentrates and equipment shall be stored in an accessible location not exposed to the hazard they protect. If housed, they shall be in a noncombustible structure. For outdoor nonautomatic systems, the authority having jurisdiction may permit the storage of foam concentrate off the premises where these supplies are available at all times. Adequate loading and transportation facilities shall be assured. Off-premises supplies shall be of the proper type for use in the systems of the given installation. At the time of a fire, these off-premises supplies shall be accumulated in sufficient quantities, before placing the equipment in operation, to ensure uninterrupted foam production at the design rate for the required period of time.

2-3.1.2 Quantity. The amount of concentrate shall be at least sufficient for the largest single hazard protected or group of hazards that are to be protected simultaneously.

2-3.1.3 Foam Concentrate Storage Tanks. Bulk liquid storage tanks shall be fabricated from or be lined with materials compatible with the concentrate.

2-3.1.4 Storage Conditions. In order to ensure the correct operation of any foam-producing system, the chemical and physical characteristics of the materials comprising the system shall be taken into consideration in design. Since such systems may or may not be operated for long periods after installation, the choice of proper storage conditions and maintenance methods will determine to a large extent the reliability and the degree of excellence of operation of the system when it is called upon to operate.

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

2-3.2 Reserve Supply.

2-3.2.1 Reserve Supply of Foam Concentrate. There shall be a readily available reserve supply of foam-producing materials sufficient to meet design requirements in order to put the system back into service after operation. This supply may be in separate tanks or compartments, in drums or cans on the premises, or available from an approved outside source within 24 hours.

2-3.2.2 Auxiliary Supplies. Other equipment that may be necessary to recommission the system, such as bottles of nitrogen or carbon dioxide for premix systems, shall also be readily available.

2-3.3 Foam Concentrate Pumps.

2-3.3.1 Design. Design and materials of construction shall be suitable for use with the type of foam concentrate to minimize corrosion, foaming, or sticking. Special attention shall be paid to the type of seal or packing used.

2-3.3.2 Capacity and Pressure. Pumps shall have adequate capacities to meet the maximum system design requirements. To ensure positive injection, the discharge pressure rating at design discharge capacity shall be sufficiently in excess of the maximum water pressure likely under any condition at the point of injection of the concentrate.

2-3.3.3 Pressure Relief. Positive displacement pumps 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. Centrifugal pumps may require pressure relief depending upon the type of driver and shut-off pressures.

2-3.3.4 Flushing. Pumps shall have adequate means for flushing with clean water after use. They shall be provided with a drain cock or valve.

2-3.3.5 Controllers. Controllers governing the starting of concentrate pumps shall be of approved types. Where control equipment listed for fire protection service is not available, suitable industrial-control equipment with adequate interrupting capacity in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, may be used.

2-4 Pipework Design.

2-4.1 General Requirements.

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

(b) Piping that is normally filled with liquids, such as the suction pipes, shall be protected from freezing when necessary.

(c) For surface application, piping from the dike or within 50 ft (15 m) of tanks not diked to the tank foam discharge outlet shall be designed to absorb the upward force and shock due to a tank roof rupture. Preferably, use steel pipe and all-welded construction. One of the following designs may be used:

1. When piping is buried, a swing joint or other suitable means shall be provided at the base of each tank riser. The swing joint may consist of approved standard weight steel, ductile or malleable iron fittings.

2. When piping, is supported aboveground, it shall not be held down for a distance of 50 ft (15 m) from the tank shell to provide flexibility in an upward direction so that a swing joint is not needed. If there are threaded connections within this distance, they shall be backwelded for strength.

3. When tank risers are 4 in. pipe size or greater, they can be welded to the tank by means of steel brace plates positioned perpendicular to the tank and centered on the riser pipe. One brace shall be provided at each shell course. This design may be used in lieu of swing joints or aboveground flexibility as described above.

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

(d) In systems with semifixed equipment on fixed roof tanks, the foam or solution laterals to each foam maker shall terminate in connections that are at a safe distance from the tanks; outside of dikes and at least 50 ft (15 m) from tanks of 50-ft (15-m) diameter or less, and one tank diameter from the shell of larger tanks. The inlets to the piping shall be fitted with corrosion-resistant metal connections provided with plugs or caps.

(e) Subsurface Injection Back-Pressure Limitations. The sizes and lengths of discharge pipe or lines used beyond the foam maker and the anticipated maximum and minimum 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. (*See A-2-4.6.1 and A-3-2.10.3.*)

(f) Valves in Systems. The laterals to each foam chamber on fixed roof tanks shall be separately valved outside the dike in fixed installations. Shutoff valves to divert the foam or solutions to the proper tank may be either in the central foam station, or at points where laterals to the protected tanks branch from the main feed line. Shutoff valves shall be located outside dikes and not less than the following distances from the shell of the tank they serve: 50 ft (15 m) for tanks less than 50 ft (15 m) in diameter; a distance of one diameter for tanks 50 ft (15 m) in diameter or larger, except that shutoff valves may be permitted at less than the above distances where adequately protected or remotely operated, subject to the approval of the authority having jurisdiction. Where two or more foam proportioners are installed in parallel discharging into the same outlet header, valves shall be provided between the outlet of each device and the header. The water line to each proportioner inlet shall be separately valved.

For subsurface applications, each foam delivery line shall be provided with a valve and 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. When product lines are used for foam, product valving shall be arranged to ensure foam enters only the tank to be protected.

2-4.2 Pipe Materials. Pipe within the hazard area shall be steel or other alloy suitable for the pressure and temperature involved, but not less than standard weight, in accordance with current American standards. Pipe specifications normal for water use shall be permitted outside the hazard area. Where exposed to corrosive influences, the piping materials shall be corrosion resistant or protected against corrosion.

2-4.2.1 Lightweight Pipe. Lightweight pipe [schedule 10 in nominal sizes through 5 in.; 0.134 in. (3.40 mm) wall thickness for 6 in.; and 0.188 in. (4.78 mm) wall thickness for 8 and 10 in.] may be used in areas where fire exposure is improbable. Selection of pipe wall thickness shall anticipate internal pressure, internal and external pipe wall corrosion, and mechanical bending requirements.

2-4.3 Valves. All valves shall be of the indicator type (such as OS & Y or post indictator) and shall be approved. Readily accessible drain valves shall be provided for low points in underground and aboveground piping. Valve specifications normal for water use shall be permitted outside the hazard or diked area. Inside the hazard or diked area, automatic control valves and shutoff valves shall be steel or other alloy capable of withstanding exposure to expected fire temperatures.

2-4.4 Fittings.

(a) All pipe fittings shall be American standard for the pressure class involved but not less than standard weight. Fittings shall be steel or malleable iron in dry sections of the piping exposed to possible fire. All fittings subject to stress in self-supporting systems shall be steel or other alloy, or malleable iron.

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

(c) Pipe threading shall be in conformance with the American National Standards Institute (ANSI) Standard B2.1, *Pipe Threads*. Dimensions of cut- and roll-grooves and outside diameters of piping materials shall conform to the manufacturers' recommendations and the approval laboratories' certifications.

(d) Welding is preferable when it can be done without introducing fire hazards. Special care shall be taken to ensure that the openings are fully cut out and that no obstructions remain in the waterway. Welding practices shall conform to the requirements of the American Welding Society AWS D10.9, *Standard for the Qualification of Welding Procedures and Welders for Piping and Tubing*.

2-4.5 Strainers. Where solids of sufficient size may be present to obstruct openings in foam equipment, approved strainers shall be used. The strainer shall have a ratio of open basket area to inlet pipe area of at least 10 to 1.

2-4.6 Hangers, Support, and Protection for Pipework.

(a) Piping that is normally filled with liquids shall be protected from freezing when necessary.

(b) All distribution piping shall be arranged to drain and have a pitch of ½ in. per each 10 ft (4 mm per m).

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

(d) All hangers shall be of approved types. Tapping or drilling of load-bearing structural members shall not be permitted when unacceptable weakening of the structure would occur. Attachments may be made to existing steel or concrete structures and equipment supports. Where systems are of such a nature 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 such standard means of support.

2-4.7 Hydraulic Design of Piping Systems.

2-4.7.1* Pipe Sizes. Since effective protection depends on having an adequate volume of water (or solutions) at proper pressure available at the foam-making devices, each system requires individual consideration as to the size of the piping. Pipe sizes shall be so selected as to produce the proper delivery rate and pressure at the discharge outlet. See Chapter 7 of NFPA 13, *Standard for the Installation of Sprinkler Systems*, for hydraulic calculation procedures for water and solution flow. For friction losses in piping carrying foam concentrate, see NFPA 16, *Standard on Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, paragraph 4-6.4. For friction losses in piping carrying foam, see Appendix A-2-4.7.1. For the purpose of computing friction loss in foam solution piping, the following "C" factors shall be used for the Hazen and Williams formula:

Black Steel or Unlined Cast Iron Pipe	100
Galvanized Steel Pipe	120
Asbestos-Cement or Cement Lined Cast Iron Pipe	140

System piping shall be hydraulically calculated and sized in order to obtain reasonably uniform foam distribution and to allow for loss of head in water supply piping. Adjustment in pipe sizes to provide uniform discharge shall be based on a maximum variation of 15 percent from the assumed average discharge per discharge device, provided that the total system design delivers the design application rate.

2-4.7.2 Flushing After Use. Provision shall be made in the design to permit system flushing of normally empty foam concentrate and solution piping with clean water after use.

2-5 Operation and Control of Systems.

2-5.1

(a) Methods of Actuation. Systems shall be classified as manual or automatic in accordance with the method of actuation. An automatic system is one that is actuated by automatic detection equipment. Such systems also shall have means for manual actuation.

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

2-5.2 Manually Actuated Systems. Controls for these systems shall be located in an accessible place sufficiently removed from the hazard zone to permit them to be safely operated in an emergency, yet close enough to ensure operator knowledge of fire conditions. The location and purposes of the controls shall be plainly indicated, and shall be related to the operating instructions.

2-5.3 Automatically Actuated Systems.

2-5.3.1 All operating devices shall be suitable for the service conditions they will encounter. They shall neither be readily rendered inoperative, nor be susceptible to inadvertent operation, by environmental factors such as high or low temperature, atmospheric humidity or pollution, or marine conditions.

2-5.3.2 Various types of approved flammable gas or fire detection devices may be used. These detectors usually activate the system by operating the water control valve or other actuating device. All other equipment shall be so interconnected that it is also activated so that properly mixed foam solution is supplied to the foam makers and foam distributed over the hazard.

2-5.3.3 Automatic detection equipment, whether pneumatic, hydraulic, or electric, shall be provided with supervision so arranged that failure of equipment or loss of supervising air pressure or loss of electric energy will result in positive notification of the abnormal condition. See applicable sections of NFPA 72A, *Standard for the Installation, Maintenance, and Use of Local Protective Signaling Systems for Guard's Tour, Fire Alarm, and Supervisory Service*.

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

2-5.3.4 Electric automatic detection equipment and any auxiliary electric equipment, if in hazardous areas, shall be expressly designed for use in such areas. See NFPA 70, *National Electrical Code®*, Article 500, and other articles in Chapter 5.

2-5.3.5 In some special cases it may be desirable to arrange the system to shut off automatically after a predetermined operating time. This feature shall be subject to approval of the authority having jurisdiction.

2-5.3.6 The detection system shall activate a local alarm as well as an alarm at a constantly attended location. These alarms shall also be actuated when the system is operated manually.

2-6 Specifications and Plans.

2-6.1* Preliminary Approval. It is good practice for the owner or his designated representative (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.

2-6.2 Approval of Plans. Plans shall be submitted to the authority having jurisdiction for approval before installation.

2-6.3 Specifications. Specifications for foam systems shall be drawn up with care. To ensure a satisfactory system, the following items shall be in the specifications.

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

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

(c) The specifications shall include the specific tests that may be required to meet the approval of the authority having jurisdiction, and indicate how cost of testing is to be borne.

2-6.4 Plans. Preparation of plans shall be entrusted only to fully experienced and responsible persons. They shall be submitted for approval to the authority having jurisdiction before foam systems are installed or existing systems modified. These plans shall be drawn to an indicated scale or be suitably dimensioned.

2-6.4.1 Plans shall contain or be accompanied by the following information, when applicable:

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

(b) Type and percentage of foam concentrate.

(c) Required solution application rate.

(d) Water requirements.

(e) Calculations showing required amount of concentrate.

(f) Hydraulic calculations. (*See Chapter 7 of NFPA 13, Standard for the Installation of Sprinkler Systems, for hydraulic calculation procedures.*)

(g) Identification and capacity of all equipment and devices.

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

(i) Schematic wiring diagram.

(j) Explanation of any special features.

2-6.4.2 Only listed or approved concentrates, equipment, and devices shall be used in these systems.

2-6.4.3 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.

2-6.4.4 Charts showing head, delivery, efficiency, and brake horsepower curves of pumps shall be furnished by the contractor.

2-6.4.5 Where field conditions necessitate any significant change from the approved plan, corrected "as installed" plans shall be supplied for approval to the authority having jurisdiction.

Chapter 3 Foam Systems — Design Criteria

3-1 Foam Monitors and Handlines.

3-1.1* Application. This section relates to systems in which foam is applied through fixed or portable monitor or hose streams. They are suitable when used alone for extinguishment of spill fires, diked area fires, and fires in vertical fixed roof atmospheric storage tanks. They are recommended as auxiliary protection in conjunction with fixed systems. Portable hose streams are suitable for extinguishment of rim fires in open-top floating roof tanks.

3-1.2* Definitions.

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

Foam Hose Stream. A foam stream from a handline.

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

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

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

3-1.3 The Use of Foam Handlines and Monitors.

3-1.3.1 Limitations. Monitor nozzles shall not be considered as the primary means of protection for fixed-roof tanks over 60 ft (18 m) in diameter. Foam handlines shall neither be considered as the primary means of protection for fixed-roof tanks over 30 ft (9 m) in diameter nor over 20 ft (6 m) high.

NOTE: When the entire liquid surface was involved, fires in tanks up to 130 ft (39 m) in diameter have been extinguished with large-capacity foam monitors. Depending on the fixed-roof tank outage and fire intensity, the updraft due to chimney effect may prevent sufficient foam from reaching the burning liquid surface for formation of 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, will reduce the effectiveness of the foam stream. Monitors operated at grade usually are not recommended for floating roof rim fire extinguishment because of the difficulty of directing foam into the annular space. Fires in fixed-roof tanks having ruptured roofs with only limited access for foam are not easily extinguished by monitor application from ground level. Fixed foam monitors may be installed for protection of drum storage areas or diked areas.

3-1.4 Foam Application Rates. The minimum delivery rate for primary protection based on the assumption that all the foam reaches the area being protected shall be as called for below. In determining total solution flow requirements, consideration shall be given to potential foam losses from wind and other factors.

3-1.4.1 Tanks Containing Liquid Hydrocarbons. The foam solution delivery rate shall be at least 0.16 gpm/sq ft [(6.5 (L/min)/m²] of liquid surface area of the tank to be protected.

NOTE 1: Included in this section are gasohols and unleaded gasolines containing no more than 10 percent alcohol by volume. When alcohol content exceeds 10 percent by volume, protection is to be in accordance with 3-1.4.2.

NOTE 2: Flammable liquids having a boiling point of less than 100°F (37.8°C) may require higher rates of application. Suitable rates of application may be determined by test. Flammable liquids with a wide range of boiling points may develop a heat layer after prolonged burning and then may require application rates of 0.2 gpm/sq ft [8.1 (L/min)/m²] or more.

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

3-1.4.2 Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams. Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to regular foams require the use of alcohol-resistant foams. In general, alcohol-type foams may be effectively applied through foam monitor or foam hose streams to spill fires of these liquids when the liquid depth does not exceed 1 in. (25 mm). For liquids in greater depths, monitor and foam hose streams shall be limited for use with special alcohol-type foams listed for the purpose. 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. The following are minimum recommended application rates:

Type of Liquid	Solution Rate gpm/sq ft	(L/min)/m²
Methyl and ethyl alcohol	0.16	6.5
Acrylonitrile	0.16	6.5
Ethyl acetate	0.16	6.5
Methyl ethyl ketone	0.16	6.5
Acetone	0.24	9.8
Butyl alcohol	0.24	9.8
Isopropyl ether	0.24	9.8

Products such as isopropyl alcohol, methyl isobutyl ketone, methyl methacrylate monomer, and mixtures of polar solvents in general may require higher application rates. Protection of products such as amines and anhydrides, which are particularly foam destructive, require special consideration.

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

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 deterioration of performance will depend on the degree of water solubility of the fuel, i.e., the more soluble, the greater the deterioration.

3-1.4.3 Duration of Discharge.

3-1.4.3.1* The equipment shall be capable of operation to provide primary protection at the delivery rates specified in 3-1.4 for the following minimum periods of time:

(a) **Tanks Containing Liquid Hydrocarbons:**

Flash point between 100°F and 200°F (37.8°C and 93.3°C)	**50 minutes**
Flash point below 100°F (37.8°C), or liquids heated above their flash points	**65 minutes**
Crude petroleum	**65 minutes**

(b) **Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams.** Alcohol-type foams require special application procedures, as discussed in 3-1.4.2. The operation time shall be 65 minutes at specified application rates, unless the manufacturer has established, by fire test, that a shorter time may be permitted.

3-1.4.3.2 Where the system's primary purpose is for spill fire protection, the minimum discharge time shall be 10 minutes for fixed equipment and 15 minutes for portable equipment.

3-1.5 Protection of Hydrocarbon Spill Fires. The minimum foam solution delivery rate for the protection of the potential spill area shall be 0.16 gpm/sq ft [6.5

(L/min)/m²] when protein or fluoroprotein concentrate is used. When AFFF or FFFP concentrate is used, the minimum rate shall be 0.10 gpm/sq ft [4.1 (L/min)/m²].

3-1.6* Dike Area Protection. Generally, portable monitors, or foam hose streams, or both, have been adequate in fighting diked area and other spill fires. 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 fires is to extinguish and secure one area and then move on to extinguish the next section within the dike. This technique shall be continued until the complete dike area has been extinguished.

3-1.7 Foam Concentrate Supply.

3-1.7.1 Foam Concentrate Consumption Rates. The consumption rates shall be based on the percentage concentrate used in the system design (e.g., 3 or 6 percent or other if so listed or approved by the authority having jurisdiction).

3-1.7.2 General. The supplies of foam concentrate maintained shall be the sum of the quantities specified in 3-1.7.3, 3-1.7.4, and 3-1.7.5.

3-1.7.3 Minimum Discharge Rates and Times. The equipment shall be capable of operation at the rate specified in 3-1.4, for the discharge time specified in 3-1.4.3

When determining foam quantities required for tank protection, the quantity shall be based on the tank having the largest requirement.

3-1.7.4 Requirements to Fill Pipe Lines. A quantity of foam concentrate sufficient to produce foam or foam solution to fill the feed lines actually installed between the source and the most remote hazard shall also be provided. Where water flow will continue after the foam concentrate supply is depleted, and displace the solution or foam from the lines to the hazard, no added quantity is required by this subsection.

3-1.7.5 Reserve Supply of Foam Concentrate. A reserve supply of foam concentrate is required (*see 2-3.2.1*).

3-1.8 Hose Requirements. Unlined fabric hose shall not be used with foam equipment.

3-2 Fixed and Semifixed Systems for Exterior Storage Tanks.

3-2.1* Application. This section contains requirements that apply specifically to foam systems used for the protection of outdoor vertical atmospheric storage tanks containing flammable and combustible liquids by means of fixed foam discharge outlets. System design shall be based on protecting the tank requiring the largest solution flow, including supplementary hose streams.

NOTE: Tanks containing Class III combustible liquids [at or above 140°F (60°C) flash point] are not, as a rule, required to be protected by foam. Foam protection for combustible liquids may be desirable where abnormal situations exist, such as storage of high-value stocks or liquids heated above their flash points.

3-2.2* Definitions.

Fixed Foam Discharge Outlet. A device permanently attached to a tank by means of which foam is introduced into the tank.

Portable Foam Tower. A device that is brought to the scene of the fire, erected, and placed in operation for delivering foam to the burning surface of a tank after the fire starts. Portable foam towers are equipped with Type I or Type II discharge outlets shaped to apply foam inward toward the tank shell. (*See Appendix B, Figure B-1-2.1.*)

NOTE: Within the scope of this standard, monitor nozzles mounted on aerial ladders or booms are not considered portable foam towers because of the higher application rates required with such devices. See 3-1.3.

Type I Discharge Outlet. An approved discharge outlet that will conduct and deliver foam gently onto the liquid surface without submergence of the foam or agitation of the surface.

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

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

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

3-2.3 Limitations.

(a) The requirements given in this chapter are based on extrapolations of test experience and appropriate listings, and reflect the limitations known to date.

(b) Foam may 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.

(c) Fixed outlets are not recommended to discharge into horizontal or pressure tanks.

3-2.4* Minimum Discharge Times. The system shall be capable of operation at the delivery rate specified in 3-2.5.1 or 3-2.6.6 for the tank to be protected, for the following minimum periods of time. If the apparatus available has a delivery rate higher than 0.1 gpm/sq ft [4.1 (L/min)/m²], a proportionate reduction in the time figure may be made, except that the time shall not be less than 70 percent of the minimum discharge times shown.

Tanks Containing Liquid Hydrocarbons	Type I Foam Discharge Outlet	Type II Foam Discharge Outlet
Flash point between 100°F and 200°F (37.8°C and 93.3°C)	20 minutes	30 minutes
Flash point below 100°F (37.8°C), or liquids heated above their flash points	30 minutes	55 minutes
Crude petroleum	30 minutes	55 minutes

3-2.5 Surface Application Systems for Fixed-Roof Storage Tanks.

3-2.5.1 Foam Application Rates for Tanks Containing Liquid Hydrocarbons. The foam solution delivery rate shall be at least 0.1 gpm/sq ft [4.1 (L/min)/m²] of liquid surface area of the tank to be protected.

NOTE 1: Included in this section are gasohols and unleaded gasolines containing no more than 10 percent alcohol by volume. When alcohol content exceeds 10 percent by volume, protection is to be in accordance with 3-2.7.

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

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

3-2.5.2* Foam Discharge Outlets. For the protection of a flammable liquid contained in a vertical fixed-roof atmospheric storage tank, discharge outlets shall be attached to the tank. Where two or more discharging outlets are required, the outlets shall be equally spaced around the tank periphery and each outlet shall be sized to deliver foam at approximately the same rate. Fixed discharge outlets shall be securely attached at the top of the shell and so located or connected as to preclude the possibility of the tank contents overflowing into the foam lines. They shall be securely attached so that displacement of the roof is not likely to subject them to serious damage.

(a) Tanks shall be provided with approved discharge outlets as set forth below:

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

NOTE: It is suggested that, for tanks above 200 ft (60 m) in diameter, at least one additional discharge outlet be added for each additional 5000 sq ft (465 m²) of liquid surface or fractional part thereof. Since there has been limited experience with foam application to fires in fixed-roof tanks over 140 ft (42 m) in diameter, requirements for foam protection on tanks above this size are based on extrapolation of data from successful extinguishments in smaller tanks. Tests have shown that foam may travel effectively across at least 100 ft (30 m) of burning liquid surface. On fixed-roof tanks of over 200 ft (60 m) diameter, subsurface injection may be used to reduce foam travel distances.

(b) Fixed outlets shall be provided with an effective and durable seal, frangible under low pressure, to prevent entrance of vapors into foam outlets and pipelines. Fixed outlets shall be provided with suitable inspection means to permit proper maintenance and for inspection and replacement of vapor seals.

3-2.6 Subsurface Application to Fixed-Roof Storage Tanks Containing Liquid Hydrocarbons.

3-2.6.1* General. Subsurface foam injection systems are suitable for protection of liquid hydrocarbons in vertical fixed-roof atmospheric storage tanks.

NOTE: For pertinent information regarding fire fighting operations, see A-3-2.6.1.

3-2.6.2 Limitations.

(a) Subsurface injection systems are suitable neither for protection of Class IA hydrocarbon liquids nor for the protection of alcohols, gasohols, esters, ketones, aldehydes, anhydrides, etc. Liquid hydrocarbons that contain such foam-destructive products may require higher application rates. Some foams may fail to extinguish unleaded premium gasoline fires when using subsurface discharge at the usually required rate. In such cases, the manufacturer of the foam concentrate shall be consulted for recommendations.

(b) Subsurface or semisubsurface injection systems are not recommended for open-top or covered floating roof tanks because of the possibility of improper distribution of foam to the fuel surface.

3-2.6.3 Foam Discharge Outlets. The discharge outlet into the tank may be the open end of a foam delivery line or product line. Outlets shall be sized so that foam generator discharge pressure and foam velocity limitations are not exceeded. The foam velocity at the point of discharge into the tank contents shall not exceed 10 ft per sec (3 m per s) for Class IB liquids or 20 ft per sec (6 m per s) for other type liquids unless actual tests prove higher velocities are satisfactory. Where two or more outlets are required, they shall be located so that the foam travel on the surface does not exceed 100 ft (30 m). Each outlet shall be sized to deliver foam at approximately the same rate. For even foam distribution, outlets may be shell connections or may be fed through a pipe manifold within the tank from a single shell connection. Rather than installing additional tank nozzles, shell connections may be made in manway covers.

(a) Tanks shall be provided with discharge outlets as set forth in Table 3-2.6.3.

Table 3-2.6.3

Tank Diameter Feet	Meters	Flash Point below 100°F (37.8°C)	Flash Point 100°F (37.8°C) or Higher
Up to 80	24	1	1
Over 80 to 120	24 to 36	2	1
Over 120 to 140	36 to 42	3	2
Over 140 to 160	42 to 48	4	2
Over 160 to 180	48 to 54	5	2
Over 180 to 200	54 to 60	6	3
Over 200 ft (60 m) add one outlet for each additional		5000 sq ft (465 m²)	7500 sq ft (697 m²)

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

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

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

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

3-2.6.4 Foam Discharge Outlet Elevation. Foam discharge outlets shall be so located as not to discharge into a water bottom. This may be accomplished by having the outlets located above the highest water level or draining the water in the cases where outlets are located below the highest water level, prior to putting the foam system into operation. If this is not accomplished, efficiency will be reduced as a result of dilution of the foam, prolonging or preventing extinguishment.

3-2.6.5* Foam Concentrates and Equipment. Foam concentrates and equipment for subsurface injection shall be listed for this purpose.

3-2.6.6 Foam Application Rates. For tanks containing liquid hydrocarbons, the foam solution delivery rate shall be at least 0.10 gpm/sq ft [(4.1 L/min)/m^2] of liquid surface area of the tank to be protected. The maximum rate shall be 0.20 gpm/sq ft [8.1 (L/min)/m^2].

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

3-2.6.7 Minimum Discharge Time. The system shall be capable of operation at the delivery rate specified in 3-2.6.6 for the tank to be protected for the minimum period of time specified in 3-2.4 for Type II foam discharge outlets.

3-2.7* Fixed-Roof Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams. Water-soluble and certain flammable and combustible liquids and polar solvents that are destructive to regular foams require the use of alcohol-resistant foams. Systems using these foams require engineering consideration. Conditions other than routine may require that the higher application rates be used. 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.

The following are minimum application rates:

Type of Liquid	Solution Rate gpm/sq ft	(L/min)/m^2
Gasohols containing more than 10 percent alcohol by volume	0.1	4.1
Methyl and ethyl alcohol	0.1	4.1
Acrylonitrile	0.1	4.1
Ethyl acetate	0.1	4.1
Methyl ethyl ketone	0.1	4.1
Acetone	0.15	6.5
Butyl alcohol	0.15	6.5
Isopropyl ether	0.15	6.5

Products such as isopropyl alcohol, methyl isobutyl ketone, methyl methacrylate monomer, and mixtures of polar solvents in general may require higher application rates. Protection of products such as amines and anhydrides, which are particularly foam destructive, require special consideration.

Solution transit time (the elapsed time between injection of the foam concentrate into the water and the induction of air) may be limited, depending on the characteristics of the foam concentrate, the water temperature, and the nature of the hazard protected. The maximum solution transit time of each specific installation shall be within the limits established by the manufacturer.

NOTE 1: The solvent and the fire resistance of alcohol-type air foam may be adversely affected by such factors as excessive solution transit time, the use of foam-making devices not specifically designed or adequately tested for a particular alcohol foam application, operating pressure, failure to maintain proportioning within the recommended concentration limits, the method of application, and the characteristics of the particular solvent to which the foam is to be applied.

NOTE 2: For protection of highly toxic combustible or flammable liquids, high application rates may be desirable to reduce respiratory hazard to personnel for more rapid coverage of the tank contents.

Alcohol-type foams require gentle surface application by Type I devices unless listed as suitable for application by Type II devices. The operation time shall be 30 minutes at the specified application rate for Type I discharge outlets and 55 minutes for Type II discharge outlets.

3-2.8 Supplementary Protection.

3-2.8.1* Supplementary Protection. It is desirable that at least one portable tower or portable monitor be provided as supplemental protection in the event that a fixed discharge outlet is damaged. Where portable towers are used for primary protection, see Appendix B.

3-2.8.2* Supplementary Foam Hose Stream Requirements. Approved foam hose stream equipment shall be provided in addition to tank foam installations as supplementary protection for small spill fires. The minimum number of fixed or portable hose streams required shall be as specified in the following table and shall be available to provide protection of the area. For the purpose of this requirement, the equipment for producing each foam stream shall have a solution rate of at least 50 gpm (189 L/min) with the minimum number of hose streams shown as follows:

Diameter of Largest Tank	Minimum number of hose streams required
Up to 65 ft (19.5 m)	1
65 to 120 ft (19.5 to 36 m)	2
Over 120 ft (36 m)	3

Additional foam-producing materials shall be provided to permit operation of the hose stream equipment simultaneously with tank foam installations specified for the period set forth in the following table:

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

*Based on simultaneous operation of the minimum number of 50 gpm (189 L/min) hose streams required. Adjustments may be made where streams of greater capacity are provided.

NOTE: In the case of alcohol-type foam, solution transit time limitations may require the use of separate water and foam concentrate lines and that the introduction of the foam concentrate be accomplished close to the foam nozzle rather than in the central foam house.

3-2.9 Foam Concentrate Supply.

3-2.9.1 General. The supplies of foam concentrate maintained shall be the sum of the quantities specified in 3-2.8.2, 3-2.9.3, 3-2.9.4, and 3-2.9.5.

3-2.9.2 Foam Concentrate Consumption Rates. The consumption rate shall be based on the percentage concentrate used in the system design (e.g., 3 or 6 percent or other if so listed or approved by the authority having jurisdiction).

3-2.9.3 Requirements for Tanks. For tanks containing hydrocarbon liquids, the equipment shall be capable of operating at the flow rate specified in 3-2.5.1 or 3-2.6.6 for the period of time specified in 3-2.4.

For tanks containing water-soluble or other foam-destructive liquids, the equipment shall be capable of operating at the flow rate, and for the application time specified in 3-2.7.

When determining foam quantities required for tank protection, the quantity shall be based on the tank having the largest requirement.

3-2.9.4 Requirements to Fill Pipelines. A quantity of foam concentrate sufficient to produce foam or foam solution to fill the feed lines actually installed between the source and the most remote hazard shall also be provided. Where water flow will continue after the foam concentrate supply is depleted, and displace the solution or foam from the lines to the hazard, no added quantity is required by this subsection.

3-2.9.5 Reserve Supply of Foam Concentrate. A reserve supply of foam concentrate is required (*see 2-3.2.1*).

3-2.10* Semisubsurface Injection Methods. Information for the use of these methods will be found in Appendix A.

3-2.11 Floating Roof Storage Tanks.

3-2.11.1* Open-Top Floating Roof Storage Tanks. Fixed outlets are generally not required on open-top floating roof tanks. They are designed for fire prevention as well as conservation of product. Using portable equipment, it is usually possible to utilize trained personnel to extinguish fires in the annular ring. There are locations, however, where fixed protection may be desired because of value of products stored, remoteness of installation, or lack of fire fighting personnel. Suggested methods for providing fixed foam systems for open-top floating roof tanks can be found in A-3-2.11.1.

3-2.11.2* Covered Floating Roof Storage Tanks. Fixed outlets are not generally required on covered floating roof tanks. When a covered floating roof tank is not designed according to NFPA 30, *Flammable and Combustible Liquids Code*, it shall be treated as a fixed-roof tank.

3-3 Fixed Foam Spray Systems.

3-3.1* Application. This section applies to systems that are designed to discharge foam in the form of a spray, and that are intended to provide primary protection for specific hazards. These hazards may be located either outdoors or indoors.

Spray systems can be used under and around process structures and equipment, horizontal tanks, pump rooms, dip tanks, and quench tanks.

This section relates to spray discharge of foam only, as some foam spray nozzles do not produce effective water patterns for cooling purposes. For system design criteria for discharge of both water and foam, refer to NFPA 16, *Standard on Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*, and NFPA 16A, *Recommended Practice for the Installation of Closed-Head Foam-Water Sprinkler Systems.*

NOTE 1: Spray foam applied externally to tanks or vessels has the added advantages of cooling and insulating the tanks or vessels while the spill fire is being extinguished. Overhead pipework for overhead applicators must neither obstruct normal operations nor impose an undue load on the roof structure. While foam is not considered an effective agent for extinguishing three-dimensional running flammable liquid fires, it can control the pool fire underneath the running fire, thus permitting control by other means.

NOTE 2: These systems may also be used to protect small outdoor open-top tanks having a liquid surface area not exceeding 200 sq ft (18.6 m²).

3-3.2 Definitions.

Fixed Foam Spray Systems. A foam system designed to produce and distribute foam as a uniform spray over the hazard to be protected.

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

Nonair-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.

3-3.3 System Design. The features and limitations listed below shall be considered when selecting one of the many variations of this type of system.

3-3.3.1 Limitations.

(a) The foam discharge may be carried by the wind beyond the area of the fuel spill.

(b) Foam nozzles may have small passages susceptible to blockage.

(c) Fixed foam sprays may be obstructed by equipment positioned temporarily.

(d) Overhead pipework for overhead applicators must neither obstruct normal operations; nor impose an undue load on the roof structure.

(e) Overhead application may need supplementary low-level application in order to provide coverage below large obstructions, such as aircraft in hangars.

(f) Aboveground pipework may be susceptible to damage by explosion.

(g) Generally these systems are not suitable for use on water-soluble liquids exceeding 1 in. (25 mm) in depth.

3-3.4 Foam Discharge Outlets.

3-3.4.1 Number and Location. There shall be a minimum of one discharge outlet per 100 sq ft (9.3 m^2) of protected area unless listing of discharge devices indicates a larger spacing is permitted. These outlets shall be so located as to provide good distribution throughout the protected area. However, an added advantage is gained by locating the outlets so that the foam discharge envelops the equipment within the protected area. Therefore, the discharge outlets may be concentrated over closed tanks or equipment rather than being evenly spaced throughout the protected area. These outlets are then located in plan and elevation to provide the most effective protection of the hazard.

3-3.5 Foam Application Rate.

3-3.5.1 For Protection of Liquid Hydrocarbons. The minimum rate of application of foam solution shall be 0.16 gpm/sq ft [6.5 (L/min)/m^2] for protein and fluoroprotein, and 0.10 gpm/sq ft [4.1 (L/min)/m^2] for AFFF and FFFP, based on the maximum potential fire area.

3-3.5.2 For Protection of Water-Soluble and Other Foam-Destructive Liquids. Foam solution application rates for the protection of these liquids shall be based on listings, or on manufacturer's recommendations based on specific fire tests.

3-3.6 Supply of Foam Concentrate.

3-3.6.1 General. The supplies maintained shall be the sum of the quantities specified in 3-3.6.2, 3-3.6.3, and 3-3.6.4.

3-3.6.2 Minimum Discharge Time.

(a) For area protection, the duration of foam discharge shall be a minimum of 10 minutes at the rate specified in 3-3.5. If the system discharges at a rate above the minimum, the minimum discharge time may then be reduced proportionately, but shall not be less than 7 minutes.

(b) For indoor tanks exceeding 400 sq ft (37.2 m^2) and larger liquid surface areas, apply the operating time rules for outdoor tanks.

NOTE: For open-top tanks, provision for constant freeboard must be made to ensure a foam blanket of not less than 6 in. (150 mm).

3-3.6.3 Requirements to Fill Pipelines. A quantity of foam concentrate sufficient to produce foam or foam solutions to fill the feed lines actually installed between the source and the most remote hazard shall also be provided. Where water flow will continue after the foam-producing material is depleted, and displace the solution or foam from the lines to the hazard, no added quantity is required by this subsection.

3-3.6.4 Reserve Supply of Foam Concentrate. A reserve supply of foam concentrate is required (*see 2-3.2.1*).

3-3.7 Operation. For automatic and manual operation, refer to the requirements of 2-6.2 and 2-6.3, respectively.

3-3.8 Foam System Piping. Section 2-4 shall be consulted for requirements applicable to piping, valves, pipe fittings, and hangers, including corrosion-protection coatings. In these open-head systems, galvanized pipe and fittings shall be used for normally noncorrosive atmospheres. Corrosive atmospheres may require other coatings. Pipe and fittings carrying foam concentrate shall not be galvanized.

Chapter 4 Combined Agent Systems — Design Criteria

4-1 Combined Agent Systems.

4-1.1 Application. This chapter relates to systems in which foam is applied to a hazard simultaneously or sequentially with dry chemical powder. Systems of this type combine the rapid fire extinguishing capabilities of dry chemical powders (as well as their ability to extinguish three-dimensional fires) with the sealing and securing capabilities of foam, and are of particular importance for protection of flammable liquid hydrocarbon hazards.

4-1.2 Definition.

Combined Agent System. These systems may be self-contained, and the application of each agent is separately controlled so that the agents may be used individually, simultaneously, or sequentially as the situation requires.

4-1.3 Limitations. The manufacturers of the dry chemical and foam concentrate to be used in the system shall confirm that their products are mutually compatible and satisfactory for this purpose.

Limitations imposed on either of the agents used in the system for the use of that agent alone shall also be applied to the combined agent system.

4-2 Application Rates. Minimum delivery rates for protection of a hazard, based on the assumption that all of the agent reaches the protected area, shall be as follows:

(a) AFFF solution shall be delivered at a rate of 0.10 gpm/sq ft [4.1 (L/min)/m^2] of area to be protected.

(b) The ratio of dry chemical discharge rate to AFFF discharge rate [lb (kg) dry chemical per sec/lb (kg) AFFF solution per second] shall be in the range of 0.6:1 to 5:1.

NOTE: Other types of foam may be used with dry chemicals. Test data, including application rates, ratio of discharge rates, and compatibility, should be determined by an independent testing laboratory.

4-3 Minimum Discharge Times. The equipment shall be capable of operation for a period of at least 30 seconds for each agent at the delivery rates specified in Section 4-2.

4-4 Supply of Agents.

4-4.1 Foam Concentrate. The supply of foam concentrate and expellent gas shall be sufficient for delivery of foam solution for the time specified in Section 4-3 at the rate specified in Section 4-2(a), plus the reserve supply specified in 4-4.3.

4-4.2 Dry Chemical. The supply of dry chemical and expellant gas shall be sufficient for delivery at the rate selected in accordance with Section 4-2(b) for the time specified in Section 4-3, plus the reserve supply specified in 4-4.4. In addition, the supply of expellant gas shall be sufficient to blow hoses clear of dry chemical after use.

4-4.3 Reserve Supply of Foam Concentrate. There shall be a readily available reserve supply of foam concentrate sufficient to meet design requirements in order to put the system back into service after operation. This supply may be in separate tanks or compartments, in drums or cans on the premises, or available from an approved outside source within 24 hours.

4-4.4 Reserve Supply of Dry Chemical. There shall be a reserve supply of dry chemical and expellant gas, kept on the premises or available from an approved outside source within 24 hours, sufficient for one complete recharge of the system according to design requirements. This reserve supply of dry chemical shall be stored in a constantly dry area and the dry chemical shall be contained in metal drums or other containers that will prevent the entrance of moisture, even in small quantities. Prior to charging the dry chemical vessel, the dry chemical shall be carefully checked to determine that it is in free-flowing powdery condition, and the pressure or weight of the expellant gas container shall be checked as stipulated by the manufacturer to determine that it is above the required minimum.

Chapter 5 Testing and Maintenance

5-1 Flushing After Installation. In order to remove foreign materials that may have entered during installation, water supply mains, both underground and aboveground, shall be flushed thoroughly at the maximum practicable rate of flow before connection is made to system piping. The minimum rate of flow for flushing shall not be less than the water demand rate of the system, as determined by the system design. The flow shall be continued for a sufficient time to ensure thorough cleaning. Disposal of flushing water must be suitably arranged. All foam system piping shall be flushed after installation, using its normal water supply with foam-forming materials shut off, unless the hazard cannot be subjected to water flow. Where flushing cannot be accomplished, pipe interiors shall be carefully visually examined for cleanliness during installation.

5-2* Acceptance Tests. The completed system shall be tested by qualified personnel to meet the approval of the authority having jurisdiction. These tests shall be adequate to determine that the system has been properly installed, and will function as intended.

5-2.1 Inspection and Visual Examination. Foam systems shall be examined visually to determine that they have been properly installed. They shall be inspected for such items as conformity with installation plans; continuity of piping; removal of temporary blinds; accessibility of valves, controls, and gages; and proper installation of vapor seals, where applicable. Devices shall be checked for proper identification and operating instructions.

5-2.2 Pressure Tests. All piping, except that handling expanded foam for other than subsurface application, shall be subjected to a 2-hour hydrostatic pressure test at 200 psig (1379 kPa gage) or 50 psi (345 kPa) in excess of the maximum pressure anticipated, whichever is greater, in conformity with NFPA 13, *Standard for the Installation of Sprinkler Systems*. All normally dry horizontal piping shall be inspected for drainage pitch.

5-2.3 Operating Tests. Before acceptance, all operating devices and equipment shall be tested for proper function.

5-2.4* Discharge Tests. Where conditions permit, flow tests shall be conducted to ensure that the hazard is fully protected in conformance with the design specification. The following data are considered essential: static water pressure, residual water pressure at the control valve and at a remote reference point in the system, actual discharge rate, consumption rate of foam-producing material, and the concentration of the foam solution. The foam discharged shall be visually inspected to ensure that it is satisfactory for the purpose intended.

NOTE: Solution concentration may be measured by refractometric means (*see Appendix A-6-1.1.3*) or it may be calculated from solution and concentrate flow rates. Solution flow rates may be calculated by utilizing recorded inlet or end-of-system operating pressures or both. The rate of concentrate flow may be measured by timing a given displacement from the storage tank.

5-2.5 System Restoration. After completion of acceptance tests, the system shall be flushed and restored to operational condition.

5-3 Periodic Inspection. At least annually, all foam systems shall be thoroughly inspected and checked for proper operation. This shall include performance evaluation of the foam concentrate or premix solution quality or both. (*See 5-3.5 and Chapter 6.*) Deviation of results exceeding 10 percent from those recorded in acceptance testing shall be discussed immediately with the manufacturer. Regular service contracts are recommended. The goal of this inspection and testing shall be to ensure that the system is in full operating condition and that it will remain in that condition until the next inspection. The inspection report, with recommendations, shall be filed with the owner. Between the regular service contract inspections or tests, the system shall be inspected by competent personnel following an approved schedule.

5-3.1 Foam-Producing Equipment. Proportioning devices, their accessory equipment, and foam makers shall be inspected.

5-3.2 Piping. Aboveground piping shall be examined to determine its condition and that proper drainage pitch is maintained. Pressure tests of normally dry piping shall be made when visual inspection indicates questionable strength due to corrosion or mechanical damage. Underground piping shall be spot checked for deterioration at least every 5 years.

5-3.3 Strainers. Strainers shall be inspected periodically and cleaned after each use and flow test.

5-3.4 Detection and Actuation Equipment. Control valves, including all automatic and manual-actuating devices, shall be tested at regular intervals.

5-3.5 Foam Concentrate Inspection. At least annual inspection shall be made of foam concentrates and their tanks or storage containers for evidence of excessive sludging or deterioration. Samples of concentrates shall be referred to the manufacturer or qualified laboratory for quality condition testing. Quantity of concentrate in storage shall meet design requirements, and tanks or containers shall normally be kept full, with adequate space allowed for expansion.

5-4 Operating Instructions and Training. Operating and maintenance instructions and layouts shall be posted at control equipment with a second copy on file. All persons who may be expected to inspect, test, maintain, or operate foam-generating apparatus shall be thoroughly trained and kept thoroughly trained in the functions they are expected to perform.

Chapter 6 Tests for the Physical Properties of Foam

6-1 General. This chapter relates the laboratory-type tests of foam concentrate or foam-producing devices when it is desired to correlate physical characteristics with fire extinguishing properties.

6-1.1 Application. The following contain detailed laboratory procedures for the sampling and analysis of fire fighting foams.

6-1.1.1* Procedures for Measuring Expansion and Drainage Rates of Foam.

6-1.1.2* Method for Determination of Film-Forming Capability.

6-1.1.3* Concentration.

6-1.1.4* Interpretation of Foam Test Results.

6-1.1.5* Inspection of Foam Concentrate.

Chapter 7 Referenced Publications

7-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1.1 NFPA Publications. National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 11A-1988, *Standard for Medium and High Expansion Foam Systems*

NFPA 11C-1986, *Standard for Mobile Foam Apparatus*

NFPA 13-1987, *Standard for the Installation of Sprinkler Systems*

NFPA 16-1986, *Standard on Deluge Foam-Water Sprinkler and Foam-Water Spray Systems*

NFPA 16A-1983, *Recommended Practice for the Installation of Closed-Head Foam-Water Sprinkler Systems*

NFPA 18-1986, *Standard on Wetting Agents*

NFPA 20-1987, *Standard for the Installation of Centrifugal Fire Pumps*

NFPA 24-1987, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*

NFPA 30-1987, *Flammable and Combustible Liquids Code*

NFPA 34-1987, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*

NFPA 70-1987, *National Electrical Code®*

NFPA 71-1987, *Standard for the Installation, Maintenance, and Use of Signaling Systems for Central Station Service*

NFPA 72A-1987, *Standard for the Installation, Maintenance, and Use of Local Protective Signaling Systems for Guard's Tour, Fire Alarm, and Supervisory Service*

NFPA 72B-1986, *Standard for the Installation, Maintenance, and Use of Auxiliary Protective Signaling Systems for Fire Alarm Service*

NFPA 72C-1986, *Standard for the Installation, Maintenance, and Use of Remote Station Protective Signaling Systems*

NFPA 72D-1986, *Standard for the Installation, Maintenance, and Use of Proprietary Protective Signaling Systems*

NFPA 72E-1987, *Standard on Automatic Fire Detectors*

NFPA 412-1987, *Standard for Evaluating Foam Fire Fighting Equipment on Aircraft Rescue and Fire Fighting Vehicles*

NFPA 414-1984, *Standard for Aircraft Rescue and Fire Fighting Vehicles.*

Appendix A Explanatory Notes

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

A-1-4 Definitions.

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

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

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

Hydrocarbon Surfactant-type Foam Concentrates. These are synthetic foaming agents generally based on hydrocarbon surface active agent. They produce foams of widely different character (expansion and drainage times) dependent 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 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 as combination foaming/wetting agents. The appropriate listings should be consulted to determinine proper application rates and methods.

A-1-4(b), (c) In-Line Eductor. This eductor is for installation in a hose line, usually at some distance from the foam maker or playpipe, as a means of drafting air foam concentrate from a container.

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 is accordingly designed for use with specified lengths of hose or pipe 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 6 ft (1.8 m) below the eductor.

A-1-4(d) Primary-Secondary Eduction Method. This method of introducing air foam concentrate into the water stream en route to a fixed foam maker is illustrated in Figure A-1-4(d).

The unit consists of two eductors designated as the primary eductor and the secondary eductor. The primary eductor is located outside the firewall enclosure and is installed in a bypass line connected to and in parallel with the main water supply line to the foam maker. A portion of the water flows through the primary eductor and draws the concentrate from a container by means of a pickup tube.

The main water line discharges through the jet of a secondary eductor located at the foam maker proper, the mixture of water and concentrate from the primary eductor being delivered to the suction side of the secondary eductor.

Limitations.

1. The primary eductor may be installed as much as 500 ft (150 m) from the secondary eductor. The size of piping used, both in the water and the solution lines, should be as specified by the manufacturer.

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

A-1-4(e) 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 may be secured by the use of a manually controlled multiported metering valve.

Limitations.

1. The pressure on the water suction line at the pump must be essentially zero gage pressure or on the

Figure A-1-4(a) Air Foam Nozzle with Built-in Eductor.

Figure A-1-4(b) In-Line Eductor.

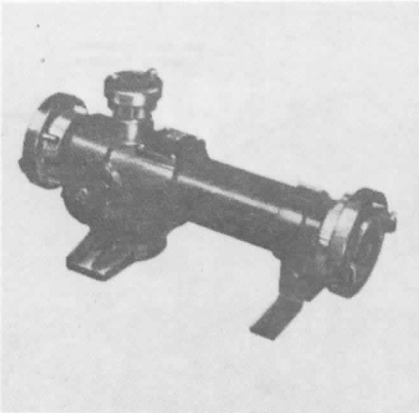
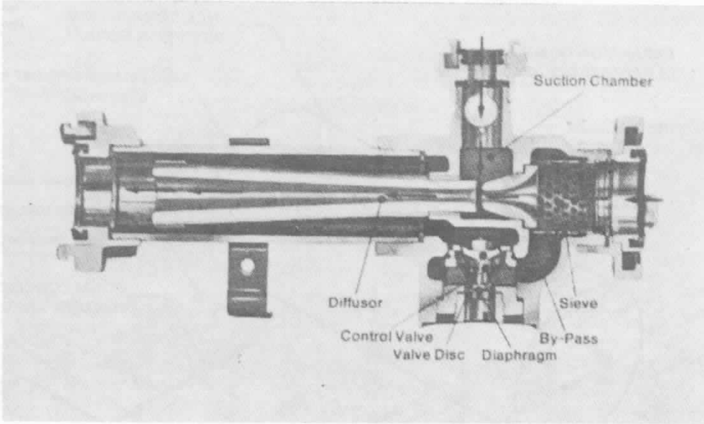



Figure A-1-4(c) In-Line Eductor.

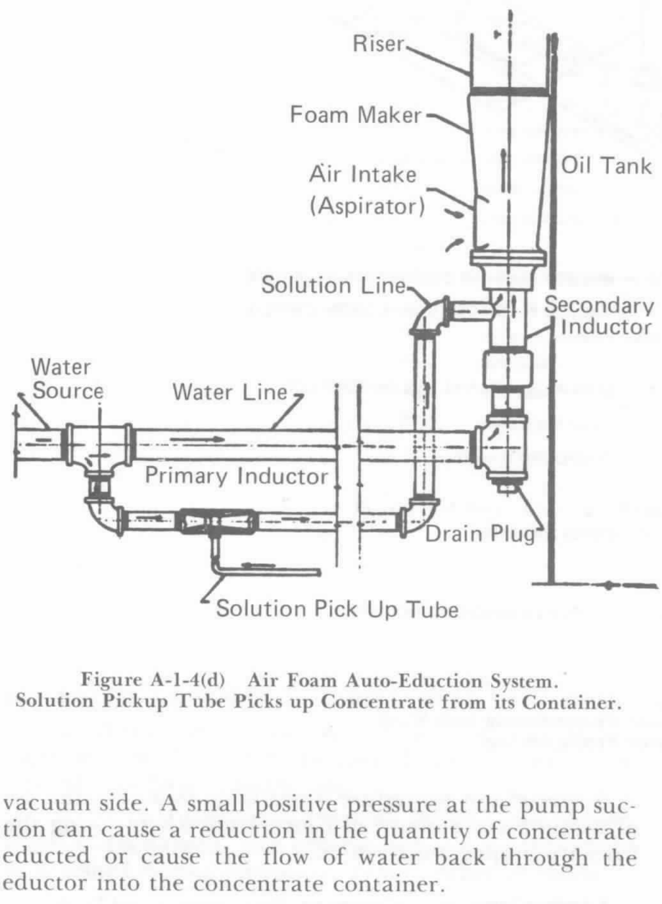


Figure A-1-4(d) Air Foam Auto-Eduction System. Solution Pickup Tube Picks up Concentrate from its Container.

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

A-1-4(f), (g) Balanced Pressure Proportioning (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 may be inserted in the line at any point between the water source and foam maker or playpipe.

To operate, the main water valve is opened and a reading of the pressure indicated on the duplex gage is taken. When both gage 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.

Limitations.

1. The capacity of the proportioner may be varied from approximately 50 to 200 percent of the rated capacity of the device.

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

3. A separate pump is required to deliver concentrate to the proportioner.

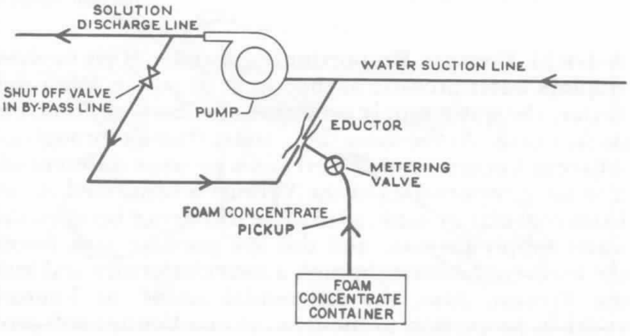


Figure A-1-4(e) Around-the-Pump Proportioner.

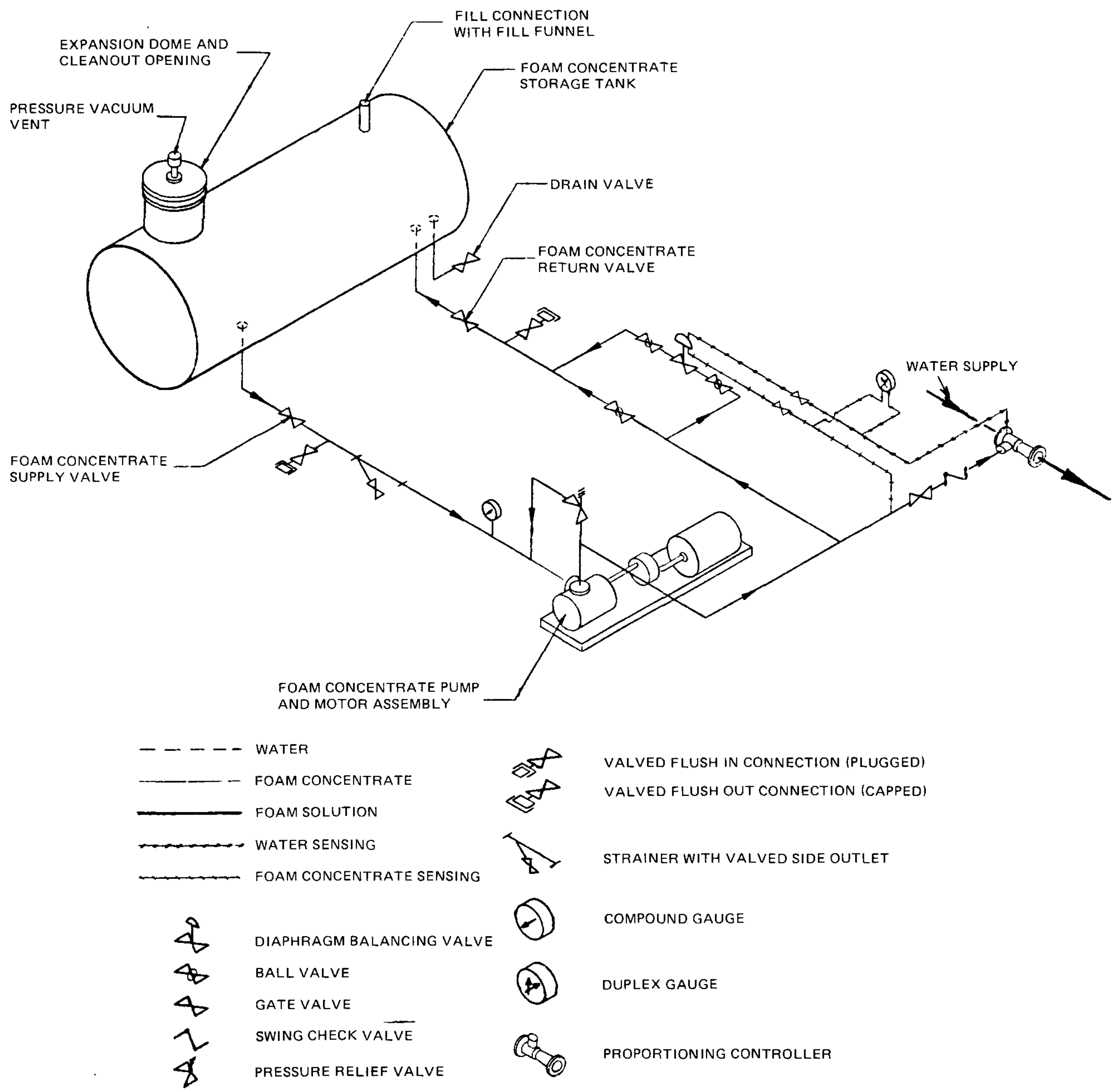


Figure A-1-4(f) Balanced Pressure Proportioning with Single Injection Point (Metered Proportioning).

A-1-4(h) 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.

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

Limitations.

1. Foam concentrate with specific gravities similar to water may create a problem by mixing.

2. The capacity of these proportioners may be varied from approximately 50 to 200 percent of the rated capacity of the device.

3. The pressure drop across the proportioner ranges from 5 to 30 psi (34 to 207 kPa) depending on the volume

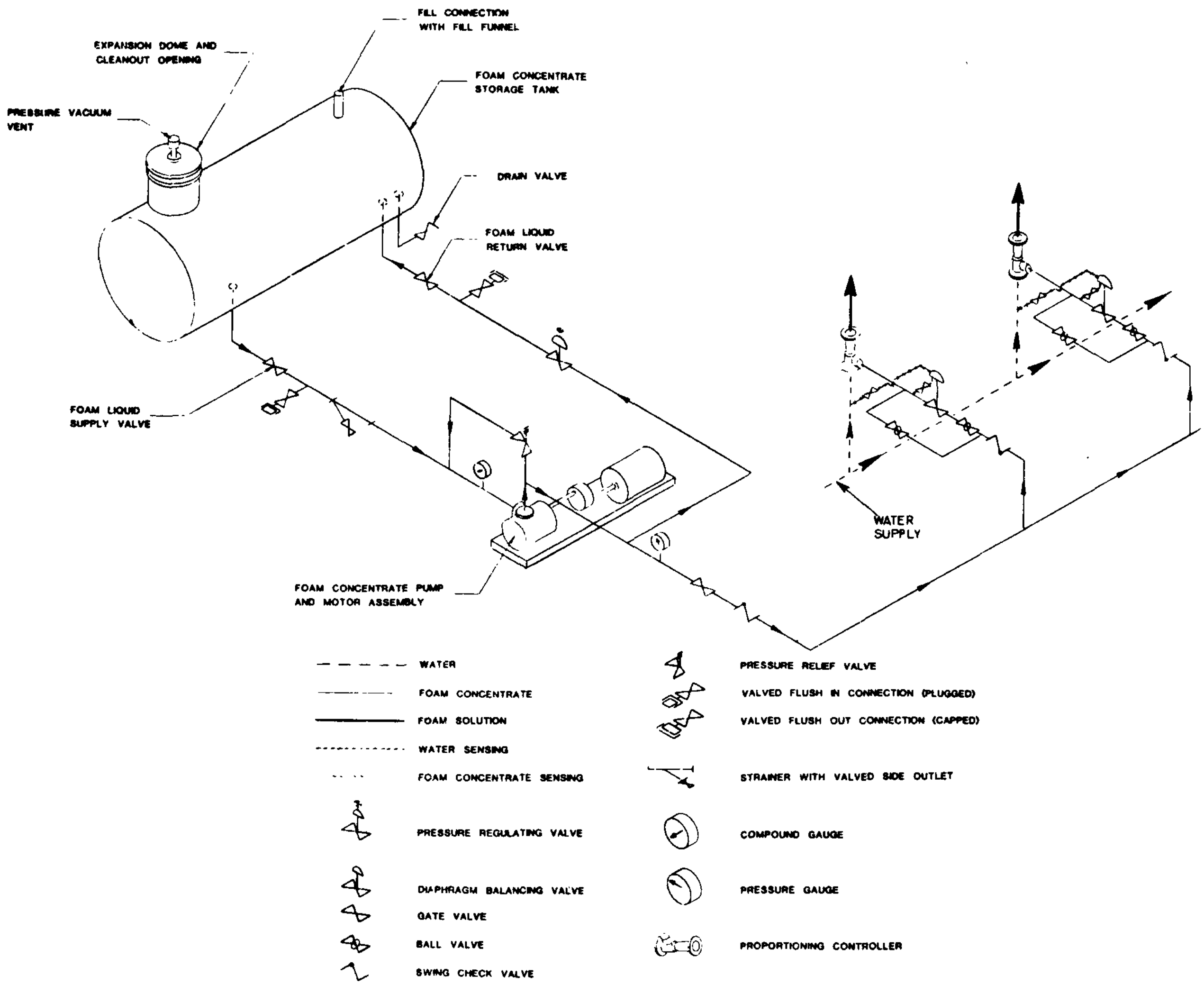


Figure A-1-4(g) Balanced Pressure proportioning with Multiple Injection Points (Metered Proportioning).

of water flowing within the capacity limits given 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 will proportion at a significantly reduced percentage at low flow rates and should not be used below minimum design flow.

A-1-4(i) 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

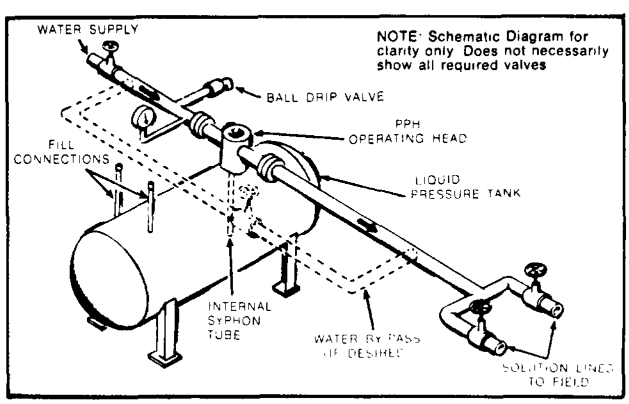


Figure A-1-4(h) Typical Arrangement of Pressure Proportioning Tank.

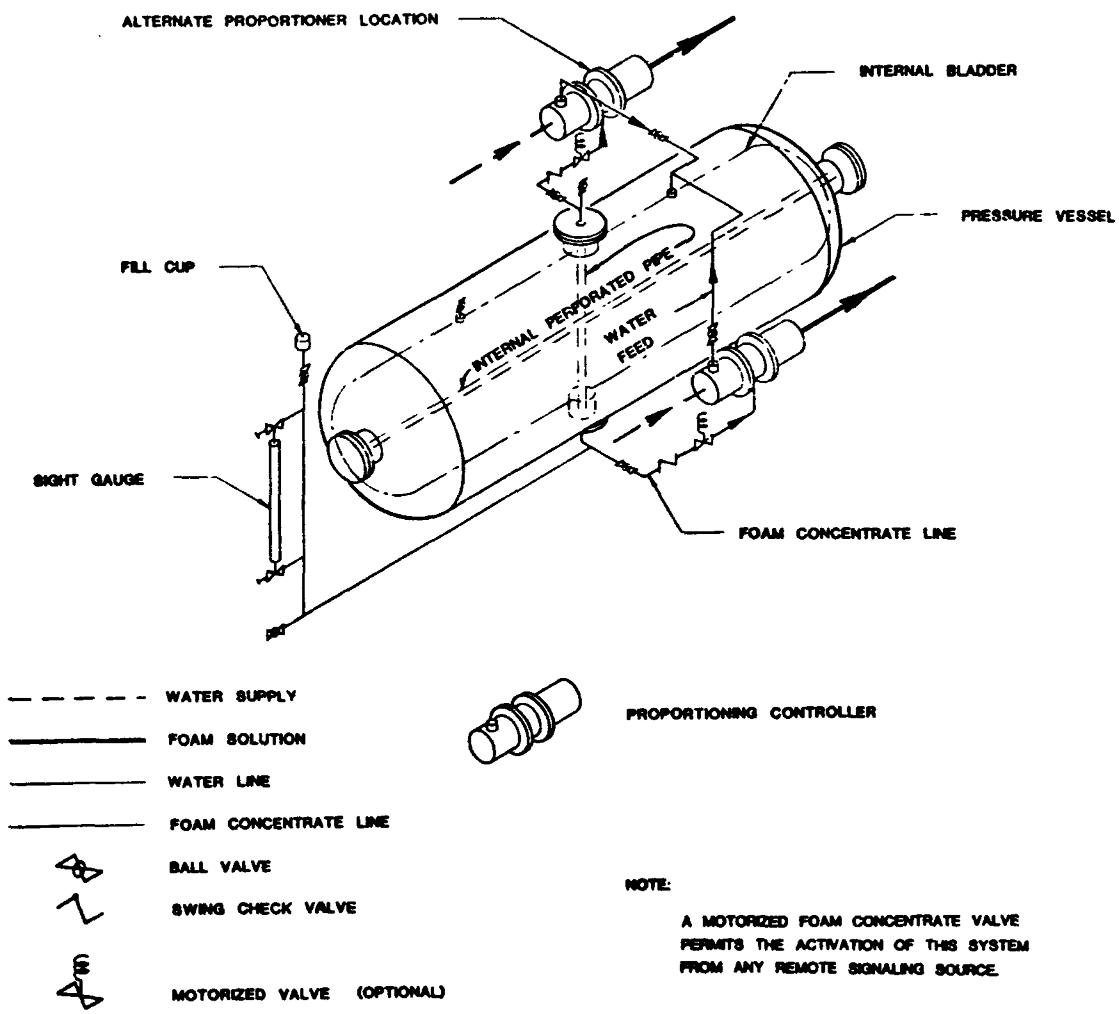


Figure A-1-4(i) Diaphragm (Bladder) Proportioning Tank.

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.

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 joins in the proper proportion with the main water supply, sending the correct foam solution to the foam makers downstream.

Limitations.

Limitations are the same as those listed under A-1-4(h), Pressure Proportioning Tank, except the system can be used for all types of concentrates.

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

A-2-4.7.1 Air Foam Friction Loss Through Piping. 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 [Figures A-2-4.6.1(a) through A-2-4.6.1(d)] are based on a foam of expansion 4, which is the value to be used for friction loss and inlet velocity calculations.

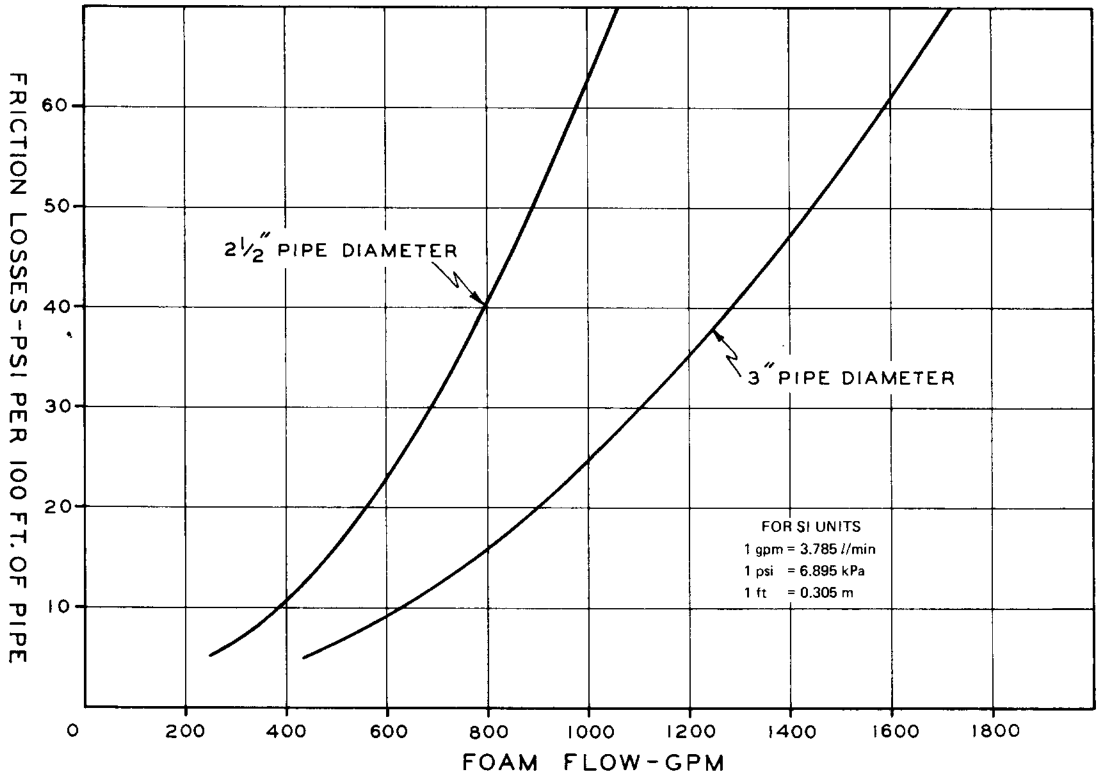


Figure A-2-4.7.1(a)

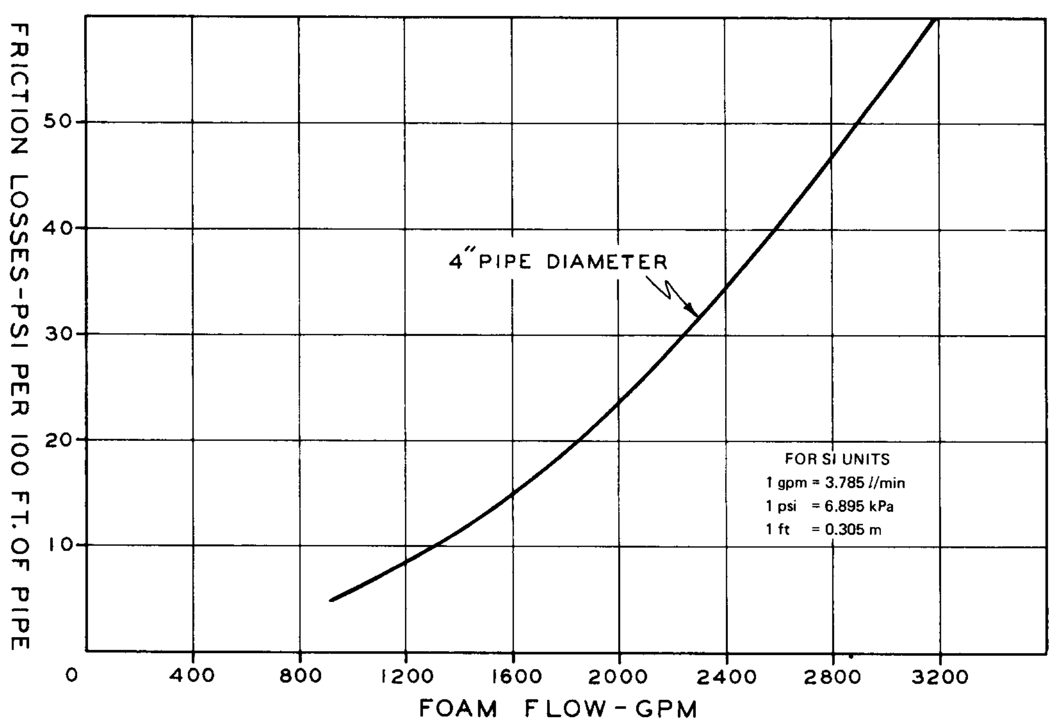


Figure A-2-4.7.1(b)

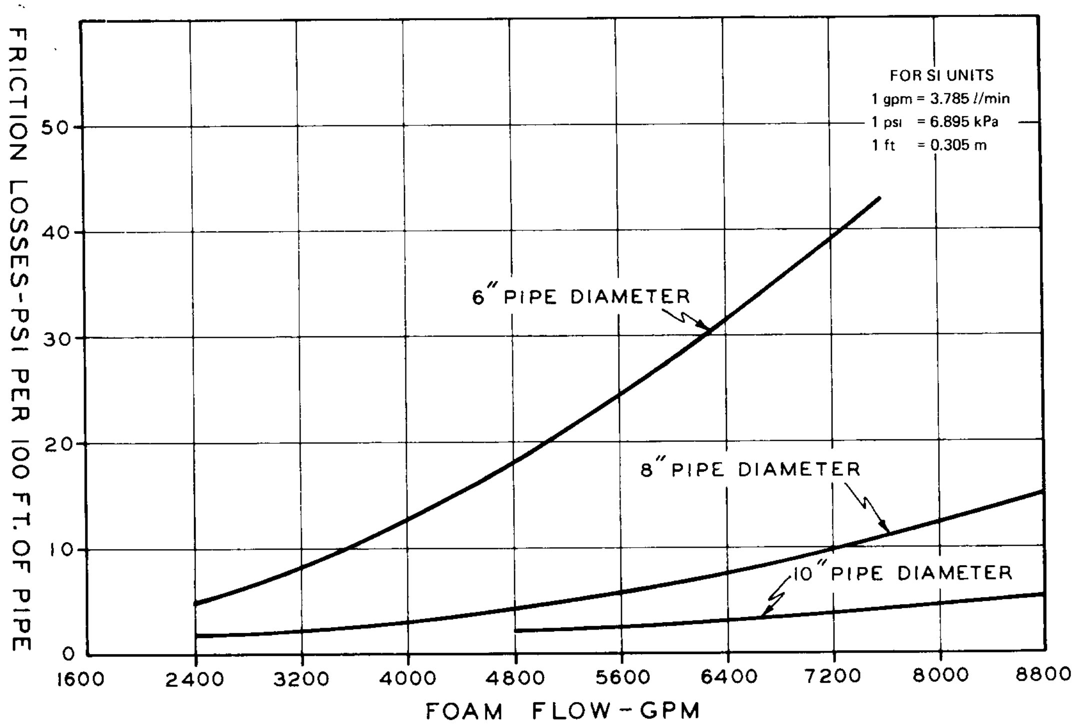


Figure A-2-4.7.1(c)

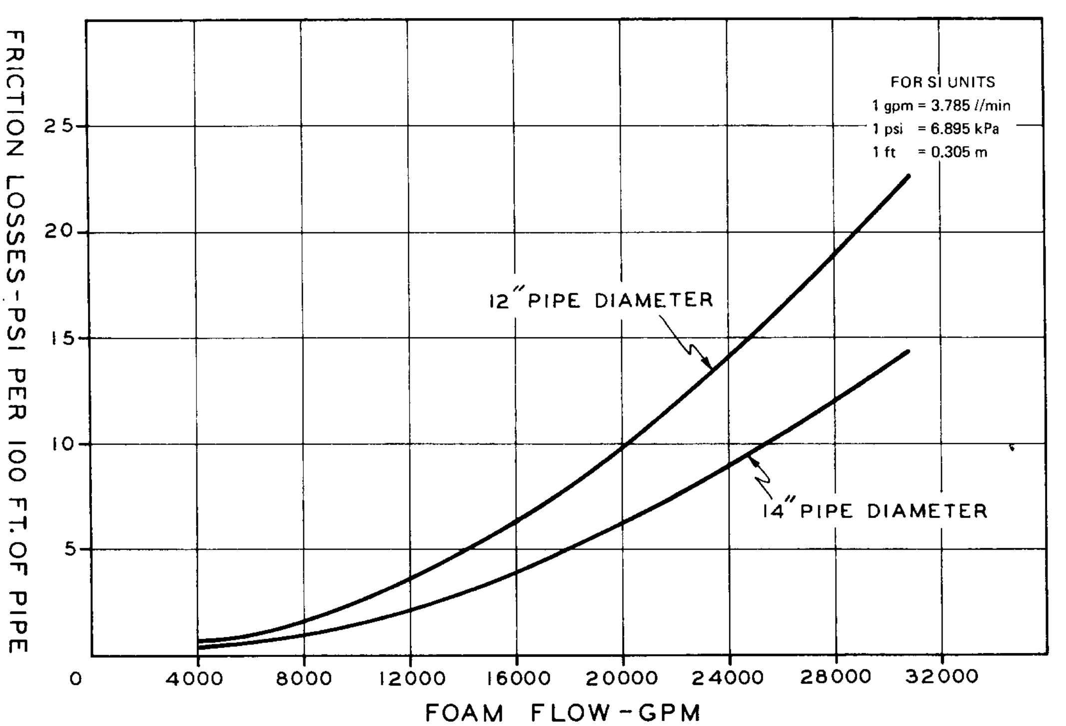


Figure A-2-4.7.1(d)

A-2-6.1 Limitations. The possibility and extent of damage by the agent must be evaluated in the choice of 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 as to the type of extinguishing agent preferred.

A-3-1.1 In centralized fixed pipe systems, the foam supply may be from hydrants installed in the system. This may also be the case where other centralized fixed pipe systems are provided. Foam hose stream protection may also be provided by portable equipment where all of the necessary devices and foam-producing materials are placed in position after the fire starts. In such cases, the number and availability of men, trucks, etc., assigned for this purpose is subject to the approval of the authority having jurisdiction.

A-3-1.2 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. It is important that the discharge characteristics of the equipment selected to produce foam nozzle and monitor streams for outdoor storage tank protection be verified by actual tests to make certain that the streams will be effective on the hazards involved.

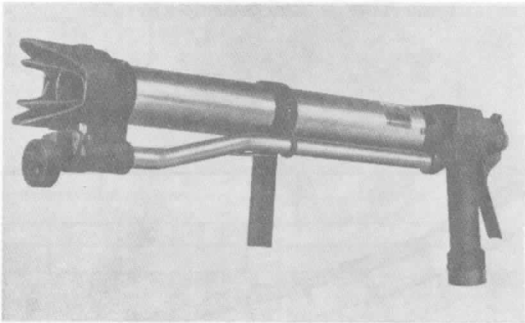


Figure A-3-1.2(a) Handline Foam Nozzle.

Figure A-3-1.2(b) Adjustable Straight-Stream-to-Fan Pattern Foam-Water Monitor.

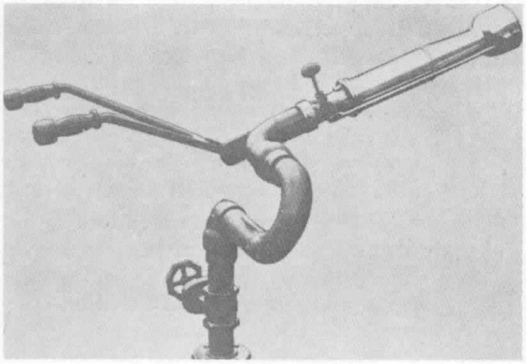


Figure A-3-1.2(c) Adjustable Straight Stream-to-Spray Foam-Water Monitor.

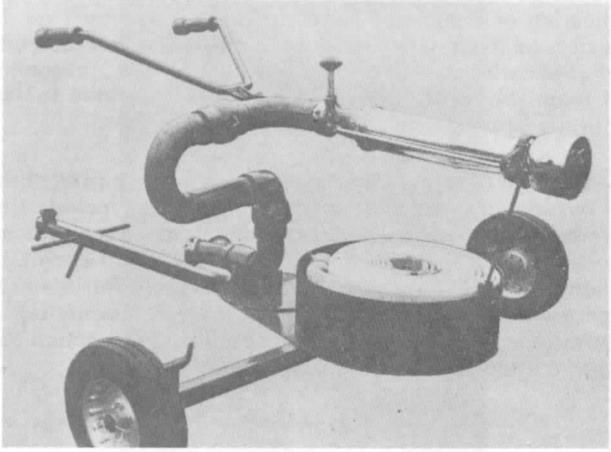


Figure A-3-1.2(d) Wheeled Portable Foam-Water Monitor.

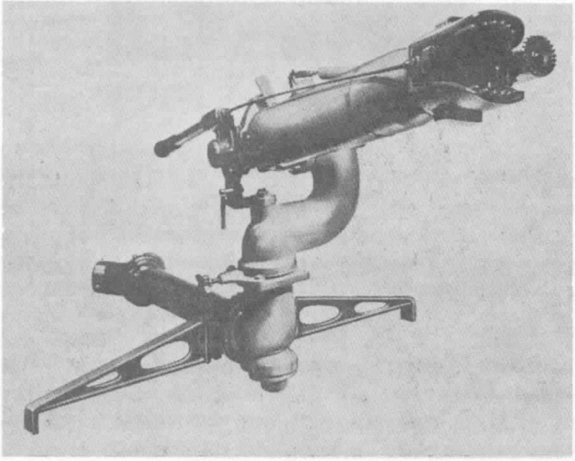


Figure A-3-1.2(e) Portable Foam-Water Monitor.

A-3-1.4.3.1 Where protection is desired for hydrocarbons having a flash point above 200°F (93.3°C), a minimum discharge time of 35 minutes should be used.

A-3-1.6 Fixed foam protection may be desirable for common diked areas surrounding multiple tanks with less than the spacing specified in NFPA 30, *Flammable and Combustible Liquids Code,* or poor fire fighting access, or both. This can be accomplished by fixed foam outlets discharging onto the inner wall of the dike, or by fixed or oscillating monitors, or by foam spray systems discharging within the diked area. Suggested design criteria are:

For fixed discharge outlets, use a solution application rate of 0.1 gpm/ft^2 [4.1 (L/min)/m^2] of area to be protected with sufficient supply of foam-producing materials for 20 minutes application to Class II liquids or 30 minutes application for Class I liquids.

For foam spray systems, see Section 3-3.
For monitor systems, see Section 3-1.

For protection of diked areas that may contain other flammable and combustible liquids requiring alcohol-type foams, protection may be provided by fixed Type I discharge outlets applying foam from the dike or by application of foams approved for the purpose by Type II devices or fixed or oscillating monitors. For recommended application rates, see the table under 3-1.4.2. Supplies of foam-producing materials should be provided for 30 minutes application.

A-3-2.1 General. These systems are 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. The systems are usually designed for manual operation but, in whole or in part, may be automatic in operation. Foam systems are the preferred protection for large outdoor tanks of flammable liquids.

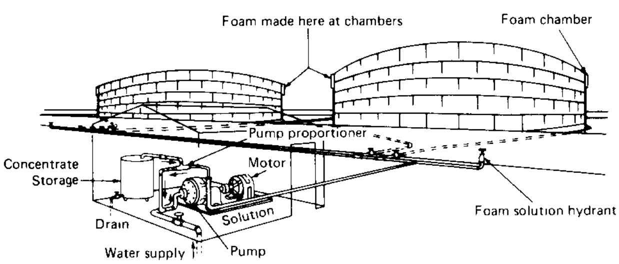


Figure A-3-2.1 Schematic Arrangement of Air Foam Protection for Storage Tanks.

A-3-2.2 Type I Discharge Outlets. Among the approved Type I discharge outlets are:

(a) Porous tube [*see Figure A-3-2.2(a)*].

(b) Foam trough along the inside of tank wall [*see Figure A-3-2.2(b)*].

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

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

Foam Trough. The trough shown schematically in Figure A-3-2.2(b) consists of sections of steel sheet formed into a chute that is securely attached to the inside of the tank wall so that it forms a descending spiral from the top of the tank to within 4 ft (1.2 m) of the bottom.

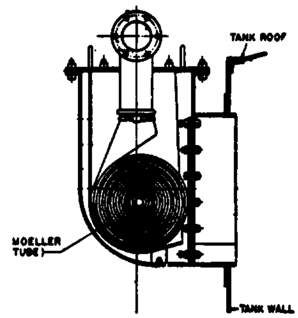


Figure A-3-2.2(a) Cross Section of a Moeller Tube Chamber. Tube is designed to unroll and fall to oil level. Foam flows through interstices in tube.

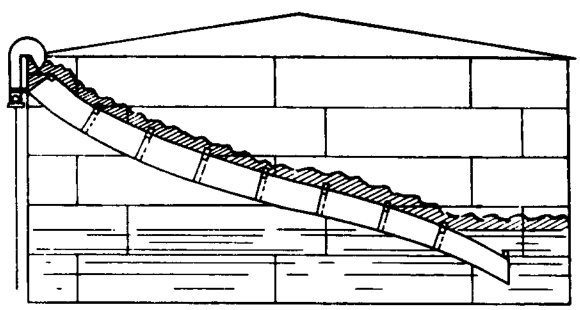


Figure A-3-2.2(b) Foam Trough.

A-3-2.4 Where protection is desired for hydrocarbons having a flash point above 200°F (93.3°C), a minimum time of 15 minutes for Type I and 25 minutes for Type II outlets should be used.

A-3-2.5.2 Unless subsurface foam injection is utilized, it may be deemed advisable to install a properly sized flanged connection on all atmospheric pressure storage tanks, regardless of present intended service, to facilitate the future installation of an approved discharge outlet if a change in service should require such installation. Figures A-3-2.5.2(a) and A-3-2.5.2(b) are typical fixed foam discharge outlets or foam chambers.

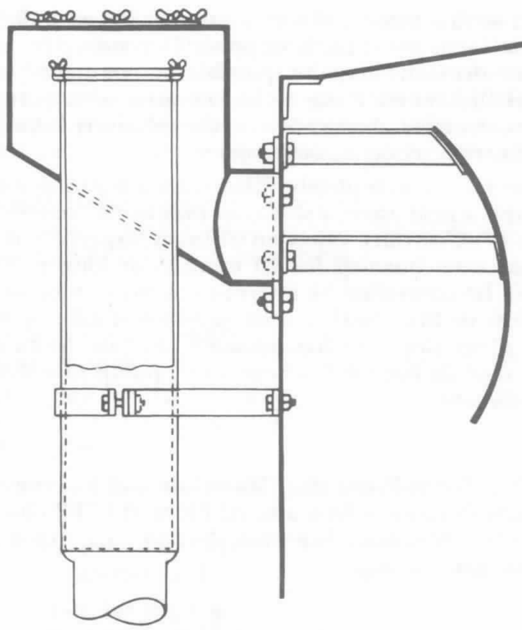


Figure A-3-2.2(c) Air Foam Chamber with Type II Outlet.

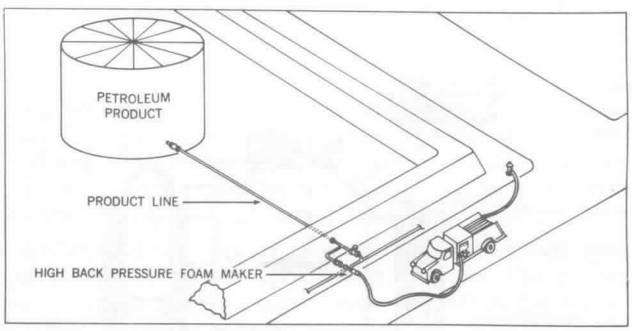
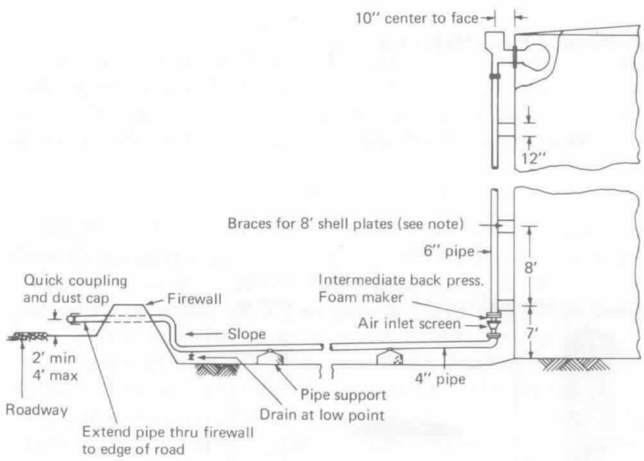


Figure A-3-2.2(d) Semifixed Subsurface Foam Installation.



For SI Units: 1 in. = 25.4 mm; 1 ft = 0.305 m.

NOTE: One brace (½ in. plate, 12 in. long) is to be provided at each shell course. This will help keep the shell in place during the early stages of the fire and prevent buckling before cooling water is applied.

Figure A-3-2.2(e) Typical Air Foam Piping for Intermediate Back-Pressure Foam System.

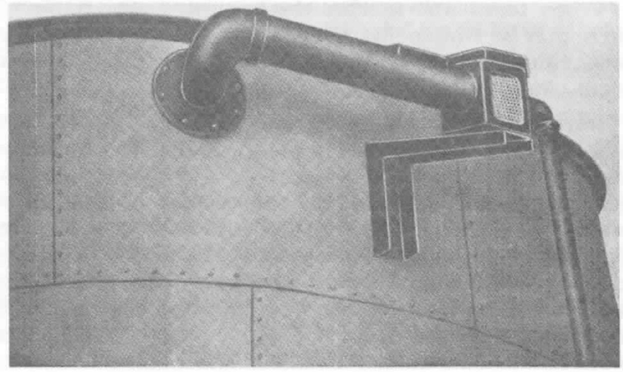


Figure A-3-2.5.2(a) Air Foam Maker in Horizontal Position at Top of Storage Tank.

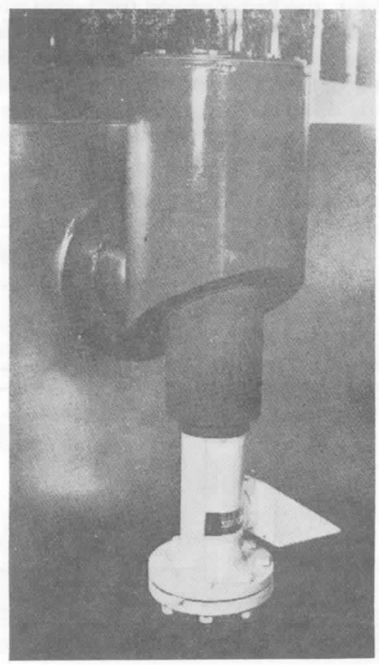


Figure A-3-2.5.2(b) Foam Chamber and Foam Maker.

A-3-2.6.1 General. 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 conduct of operations a safe distance from the tank. Thus, opportunity for establishing and maintaining an adequate foam application rate is enhanced. The following guides regarding fire attack are suggested.

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 start of foam flow to the tank. Solution pressure should be brought up to and maintained at design pressure.

When foam first reaches the burning liquid surface, there may be a momentary increase in intensity caused by 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 to disrupt the established foam blanket.

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

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

A-3-2.6.5 Foam-Producing Materials and Equipment. Optimum fluoroprotein foam, AFFF, and FFFP characteristics for subsurface injection purposes are expansion ratios between 2 and 4.

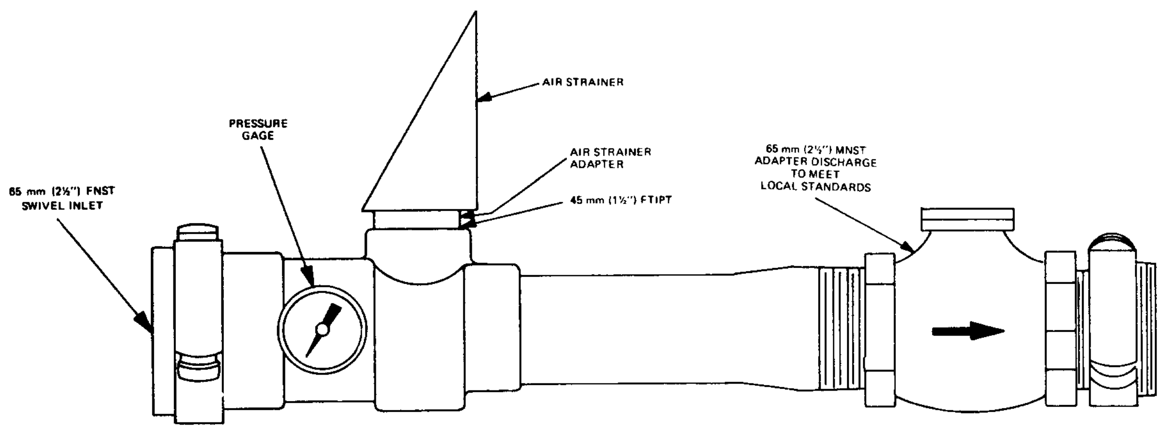


Figure A-3-2.6.5(a) Portable High Back-Pressure Foam Maker for Semifixed Systems.

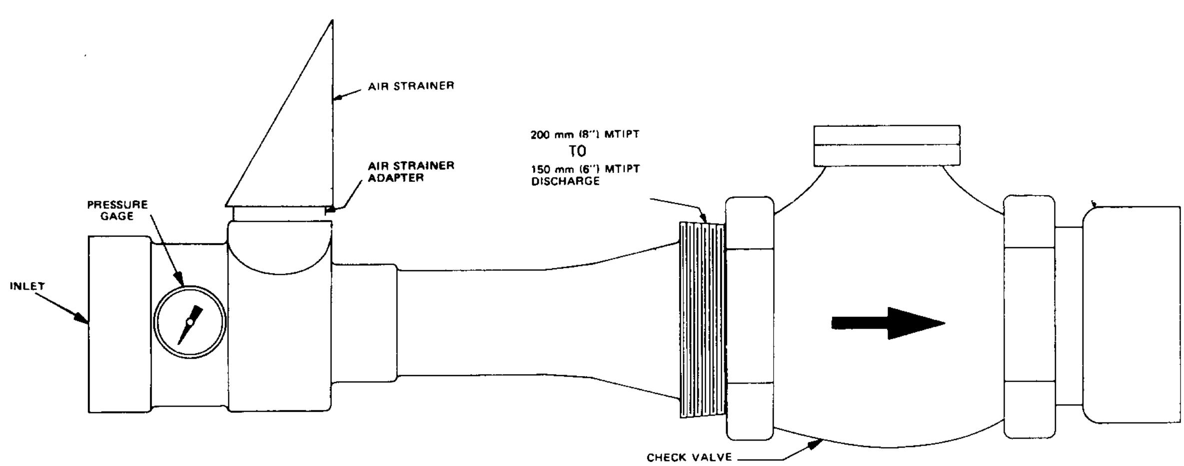


Figure A-3-2.6.5(b) Fixed High Back-Pressure Foam Maker for Fixed Systems.

A-3-2.7 Rate of Application — Water-Soluble Solvents. The system should be designed on the basis of fighting a fire in one tank at a time. The rate of application for which the system is designed should be the rate computed for the protected tank considering both the liquid surface area and the type of flammable liquid stored.

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

Liquid surface area, 40 ft (12.2 m) diameter tank	= 1257 sq ft (116.8 m^2)
Solution rate for ethyl alcohol, 0.1 gpm/sq ft [4.1 (L/min)/m^2] or 1257 × 0.1	= 126 gpm

For SI Units
Solution Rate = (116.8) (4.1) = 477 L/min

Liquid surface area, 35 ft (10.7 m) diameter tank	= 962 sq ft (89.4 m^2)
Solution rate for isopropyl ether, 0.15 gpm/sq ft [6.1 (L/min)/m^2] or 962 × 0.15	= 144 gpm

For SI Units
Solution Rate = (89.4) (6.1) = 545 L/min

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

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

A-3-2.8.1 Portable Foam Tower. One type of portable foam tower design for foam systems is illustrated in Figure B-1.2.1. Provision is made to introduce the foam or foam solutions through suitable hose connections.

A-3-2.8.2 Auxiliary foam hose streams may be supplied directly from the main system protecting the tanks (e.g., in the case of centralized fixed pipe systems) or may be provided by additional equipment. The supplementary hose stream requirements as given herein are not intended to protect against fires involving major fuel spills; rather, they are considered only as first-aid-type protection for extinguishing or covering small spills involving areas in square feet equal to that covered by about six times the rated capacity (in gpm) of the nozzle.

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

A-3-2.10 Semisubsurface Injection Methods. The arrangement of these devices may take a variety of forms. Figures A-3-2.10(a) and A-3-2.10(b) show a device that has been developed and used primarily in Sweden.

This equipment consists of an immersed container with a base hose having a length equal to the length of the container and with a main hose having a length equal to the height of the tank. The nonporous foam hose is made of a synthetic-coated nylon fabric, and is lightweight, flexible, and oil resistant. It is packed into the container in a special way to facilitate ejection. The container is provided with a cap having a seal to exclude oil from the hose container and foam supply piping. Between the inlet part and the upper part of the hose container is a bypass "shock pipe."

When the foam is forced through the inlet pipe, the air contained in the piping is compressed, the foam flows through the shock pipe, and eventually opens the cap. Then the foam will reach the container and fill the base hose and push out the main hose, which will then fill with foam. The buoyancy of the foam causes the hose to rise to the surface and foam flows forth through the open end directly onto the liquid surface.

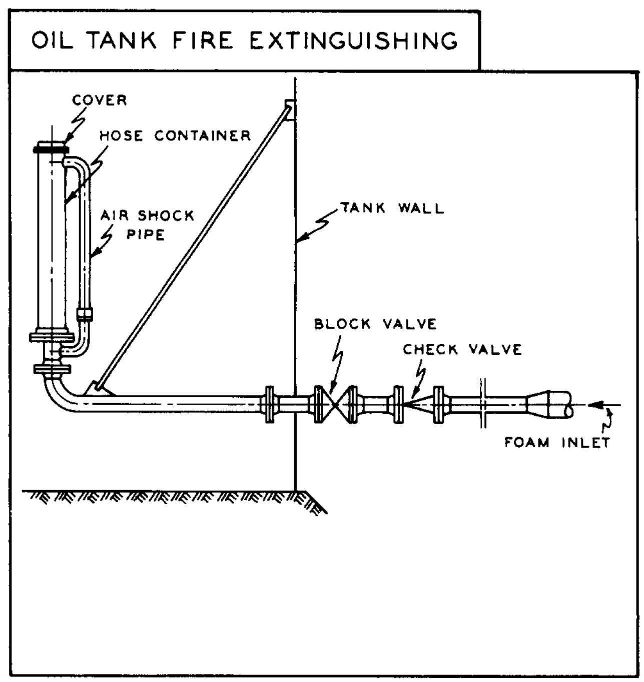


Figure A-3-2.10(a)

Discharge outlets should be provided in such sizes, numbers, and locations to meet the requirements for discharge and to distribute the foam as required by the hazard protected.

The sizing of individual discharge outlet assemblies should be in accordance with the manufacturer's ratings and recommendations and subject to the approval of the authority having jurisdiction.

The use of high back-pressure foam generators is required for semisubsurface injection. When using a water pressure of 150 psi to the foam generators, the typical system will function in tanks with heights of up to 60 ft (18 m). Water supply pressure should be determined for each individual installation or tank grouping, and will depend on the requirements of the foam generators, injection devices, and tank heights.

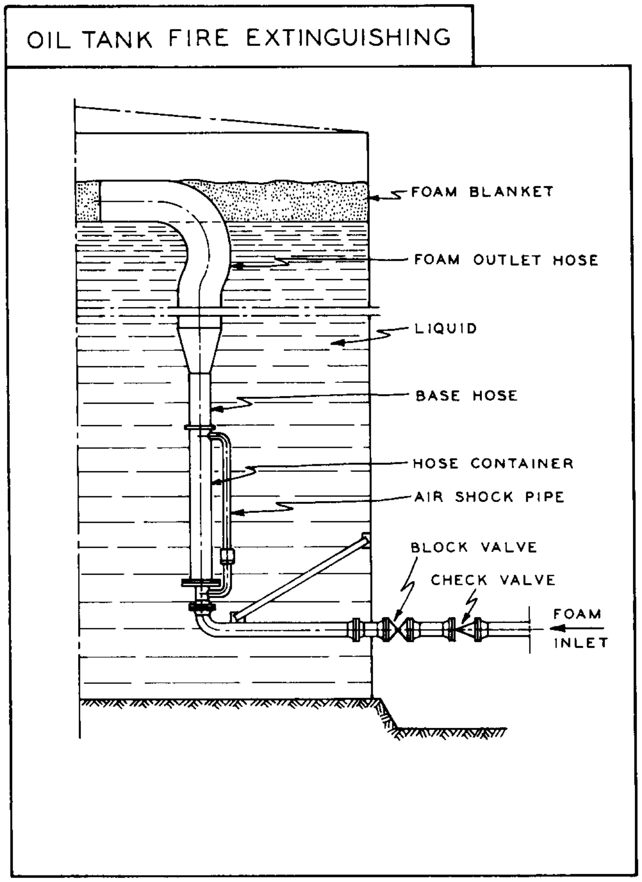


Figure A-3-2.10(b)

A-3-2.11.1 Open-Top Floating Roof Tanks. Within the scope of this standard, open-top floating roof tanks are tanks without fixed roofs that have double-deck or pontoon-type floating roofs and are constructed in accordance with the requirements set forth in NFPA 30, *Flammable and Combustible Liquids Code.* (*See Appendix C.*) The rim seal may be a mechanical shoe seal or tube seal. The tube seal may be equipped with a metal weather shield. Secondary seals of combustible or noncombustible materials may also be installed. [*See Figures A-3-2.11.1(a) through (d).*] Plastic blankets, floating diaphragms, or closures that are easily submerged are not included in this definition. Tanks so equipped should be treated as fixed-roof tanks.

Two designs are commonly used for application of foam from fixed outlets. One method discharges foam above the mechanical shoe seal, a metal weather shield, or a secondary seal. The other discharges foam below a mechanical shoe seal directly onto the flammable liquid, behind a metal weather shield directly on the tube seal envelope, or beneath a secondary seal onto the primary seal.

Operation of fixed foam fire fighting systems may be manual and/or automatic. Fixed installations are required for automatic operation; however, manual systems can be either fixed or semifixed.

Precautions should be taken with any fixed foam system design to avoid mechanical interference with the operation of the floating roof, seal systems, or rolling ladder.

(a) *Top-of-Seal Application.* To provide foam discharge either above a mechanical shoe seal, above a tube seal weather shield, or above a secondary seal use the following design:

1. Install a foam dam [*see A-3-2.11.1(c)*].

2. The number of foam discharge points are to be determined by the circumference of the tank. The maximum spacing between discharge points should be 40 ft (12.2 m) of tank circumference using a 12 in. (305 mm) high dam and 80 ft (24.4 m) of tank circumference using a 24 in. (610 mm) high dam. The foam should be a low expansion, fluid type of foam usually associated with drainage times near the "lower acceptable limit" (*see Figure A-6-1.1.4*). For secondary seal protection, a longer drainage time foam may be needed to insure piling of the foam above the seal.

3. When the discharge devices are mounted above the top of the tank shell, a foam splash board may be required [*see Figure A-3-2.11.1(e)*].

4. Calculate the foam solution application rate by using the annular ring area between the foam dam and tank shell. The minimum solution rate should be 0.30 gpm per sq ft [12.2 (L/min) m^2]. The foam concentrate supply should operate the system for 20 minutes.

NOTE: Only top-of-seal application should be used with combustible secondary seals.

(b) *Below Primary Seal or Shield Application.* To provide foam discharge below either a mechanical shoe seal, a metal weather shield, or a metal secondary seal, use the following design.

1. Install a foam dam when the distance between the top of a tube seal and top of the pontoon deck is less than 6 in. (152 mm). [*See A-3-2.11.1(c).*]

2. Foam discharge points shall be as follows:

Seal Type	Maximum Spacing Between Discharge Points
Mechanical Shoe Seal	130 ft (39 m) — Foam dam not required
Tube Seal with more than 6 in. (152 mm) between top of tube and top of pontoon	60 ft (18 m) — Foam dam not required
Tube Seal with less than 6 in. (152 mm) between top of tube and top of pontoon	60 ft (18 m) — Foam dam required

NOTE: A metal secondary seal is equivalent to a foam dam.

3. Calculate the foam solution application rate and foam concentrate supply using the following:

a. When a foam dam or metal secondary seal is installed, use the method in A-3-2.11.1(a)4.

b. When there is no foam dam installed, use the area of the annular ring between the tank shell and the edge of the floating roof. The minimum solution rate should be 0.5 gpm per sq ft [20.4 (L/min) m²] of area. The foam concentrate supply should operate the system for 10 minutes.

(c) *Foam Dam Design.* The foam dam should be circular and constructed of at least No. 10 US Standard Gage Thickness [0.134 in. (3.4 mm)] steel plate. The dam should be welded or otherwise securely fastened to the floating roof. The foam dam is designed to retain foam at the seal area, at a sufficient depth to cover the seal area while causing the foam to flow laterally to the point of seal rupture. Dam height should be at least 12 in. (305 mm). The dam should extend at least 2 in. (51 mm) above a metal secondary seal or a combustible secondary seal using a plastic-foam log. Dam height should be at least 2 in. (51 mm) higher than any burnout panels in metal secondary seals. Foam dams should be at least 1 ft (0.3 m), but no more than 2 ft (0.6 m), from the edge of the roof. To allow drainage of rain water, slot the bottom of the dam on the basis of 0.04 sq in. of slot area per sq ft (278 mm²/m²) of diked area, restricting slots to ⅜ in. (9.5 mm) in height. Excessive dam openings for drainage should be avoided to prevent loss of foam through the drainage slots. [*See Figure A-3-2.11.1(f)*].

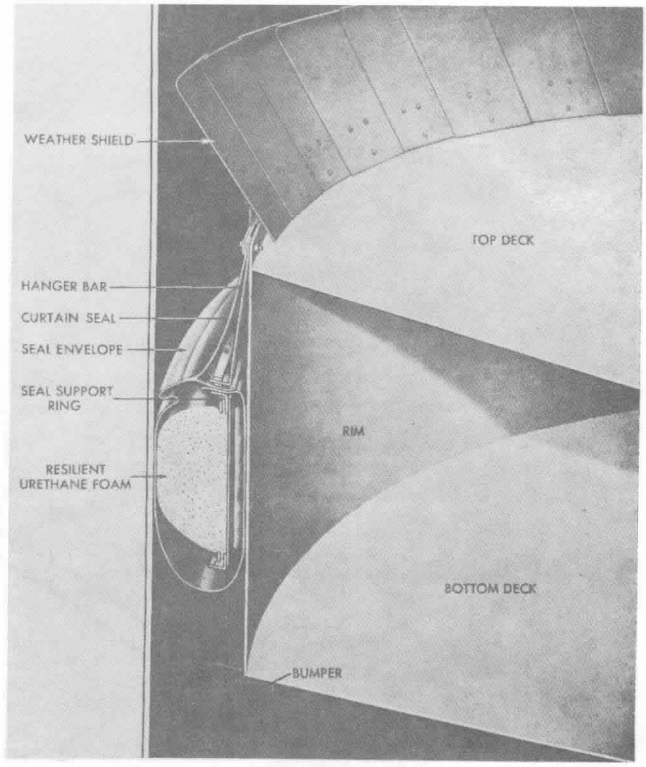


Figure A-3-2.11.1(b) Tube Seal Open-Top Floating Roof Tank.

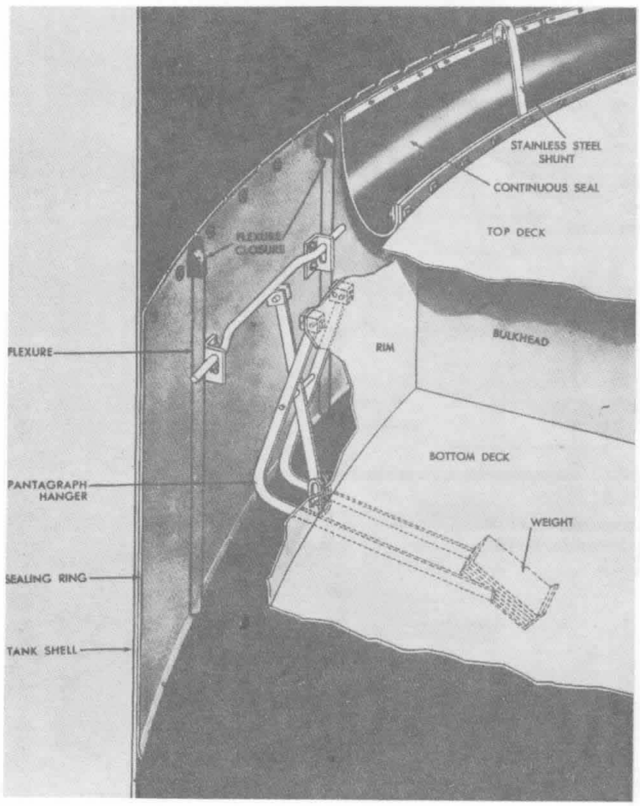


Figure A-3-2.11.1(a) Pantograph-type Seal Open-Top Floating Roof Tank.

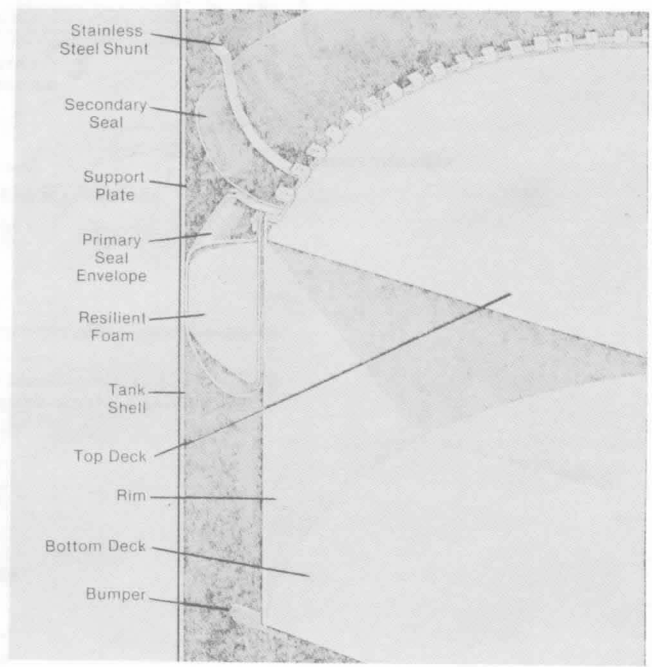


Figure A-3-2.11.1(c) Double Seal System for Floating Roofs.

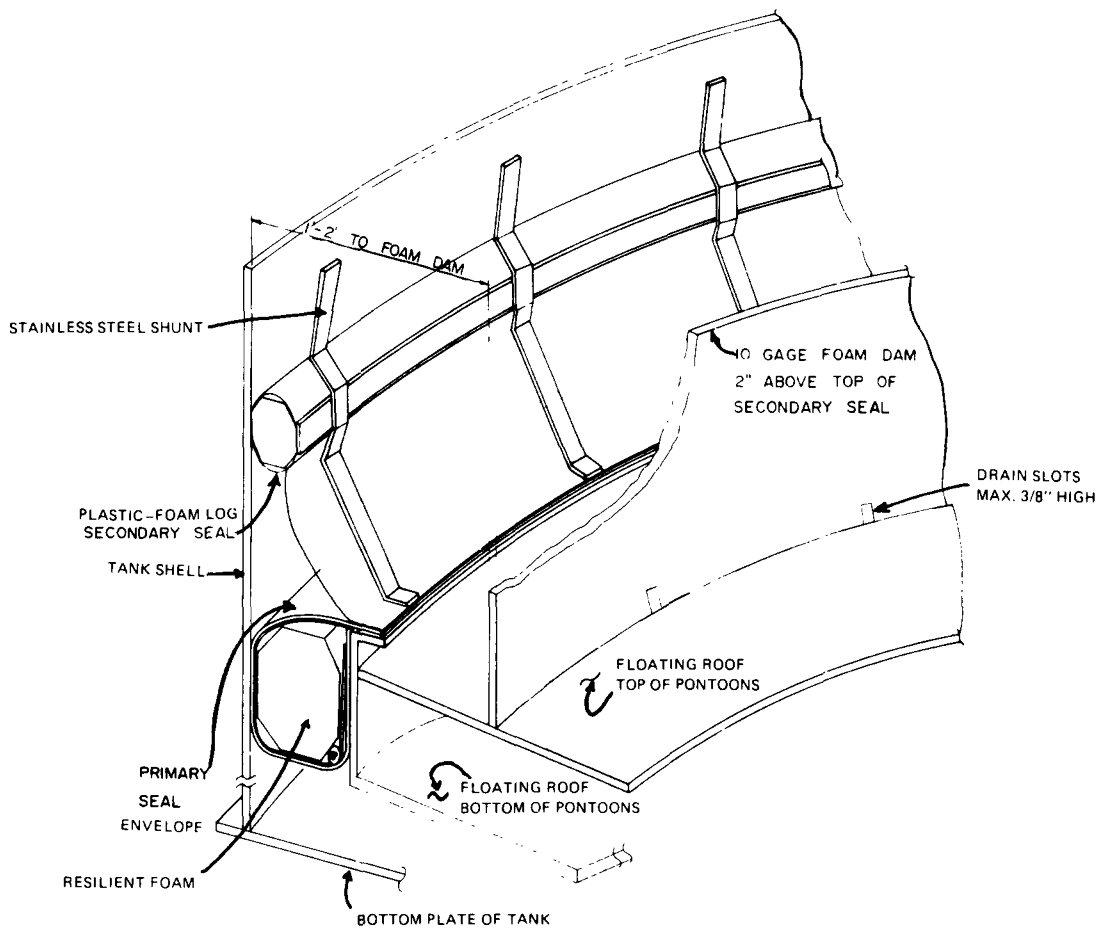
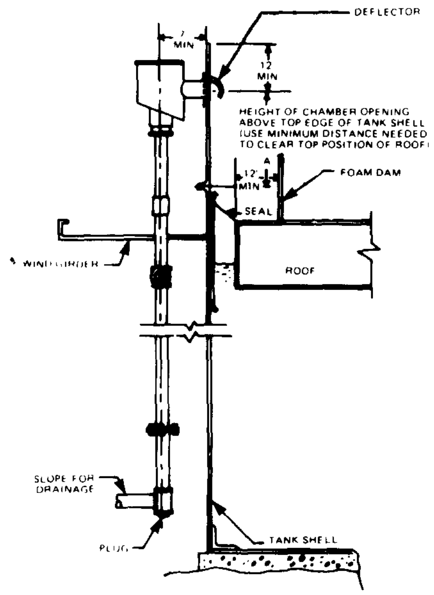
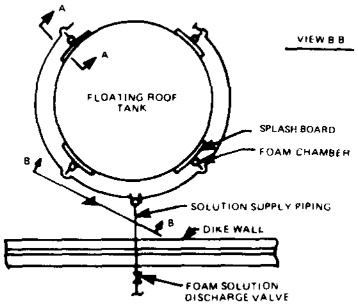


Figure A-3-2.11.1(d) Double Seal System for Floating Roofs Using a Plastic-Foam Log (Secondary Seal).



SECTION A A



TYPICAL LAYOUT OF FOAM CHAMBERS AND SOLUTION PIPING

"A" DIMENSION IS THE HEIGHT OF THE CHAMBER OPENING ABOVE THE TOP EDGE OF TANK SHELL. THE MINIMUM HEIGHT MUST CLEAR THE TOP POSITION OF THE FLOATING ROOF.

"A" DIMENSION	"L" DIMENSION
2′	10′
3′	12′
4′	14′

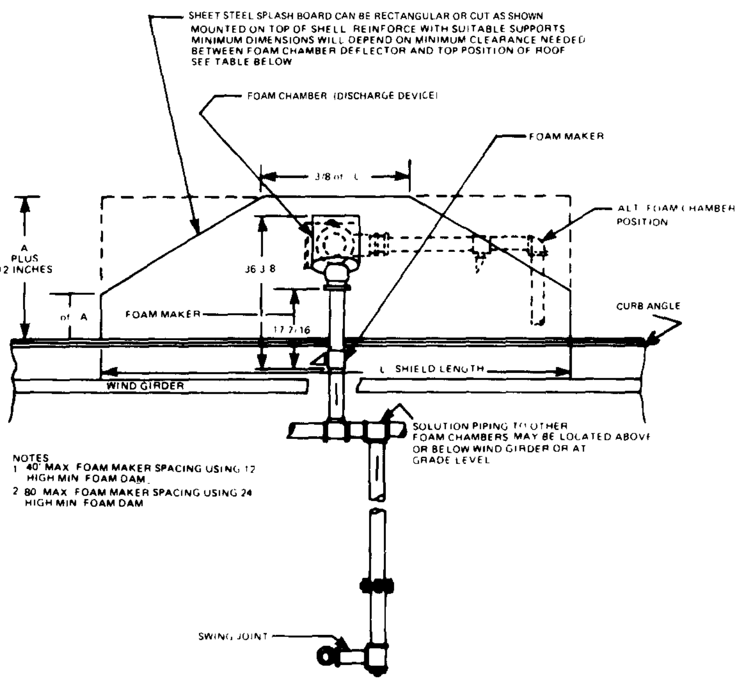


Figure A-3-2.11.1(e) Typical Foam Splash Board for Discharge Devices Mounted Above the Top of the Shell.

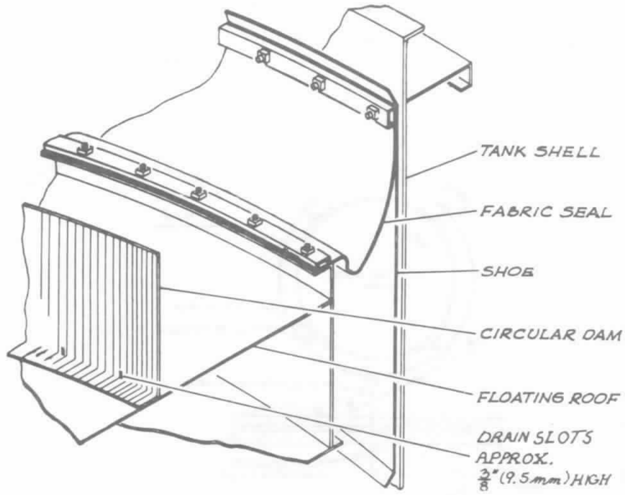


Figure A-3-2.11.1(f) Typical Foam Dam for Floating-Roof Tank Protection.

A-3-2.11.2 Covered Floating Roof Tanks. Within the scope of this standard, covered floating roof tanks covered by a fixed roof are open-vented fixed-roof tanks designed with floating roofs in accordance with the requirements specified in NFPA 30, *Flammable and Combustible Liquids Code*.

(a) When foam protection is desired for covered floating roof tanks, protection should be provided to cover the full liquid surface in the event the floating roof sinks or is destroyed. In special cases where the floating roof may be pinned at the top of the tank, and foam protection is desired below the pan, discharge outlets should be located so that the tank is protected when the pan is in the pinned position. The foam system should be designed in accordance with Chapter 3 of this standard for other than floating roof tanks, except that separately valved laterals for each foam discharge device are not required. Subsurface or semisubsurface methods are not recommended because of the possibility of improper distribution of foam.

(b) There has been no known fire experience with double-deck or pontoon-type floating roof tanks with fixed roofs and venting in accordance with NFPA 30, *Flammable and Combustible Liquids Code*. In view of the stability and excellent buoyancy of this type roof, when protection is desired, a fixed foam system for extinguishment of seal fires in the annular ring may be provided, as described in A-3-2.11.1.

(c) When foam protection is desired for fixed-roof tanks with internal floating covers made of materials other than steel, such as aluminum or plastic, protection should be designed to cover the full liquid surface in accordance with Chapter 3 of this standard for other than floating roof tanks.

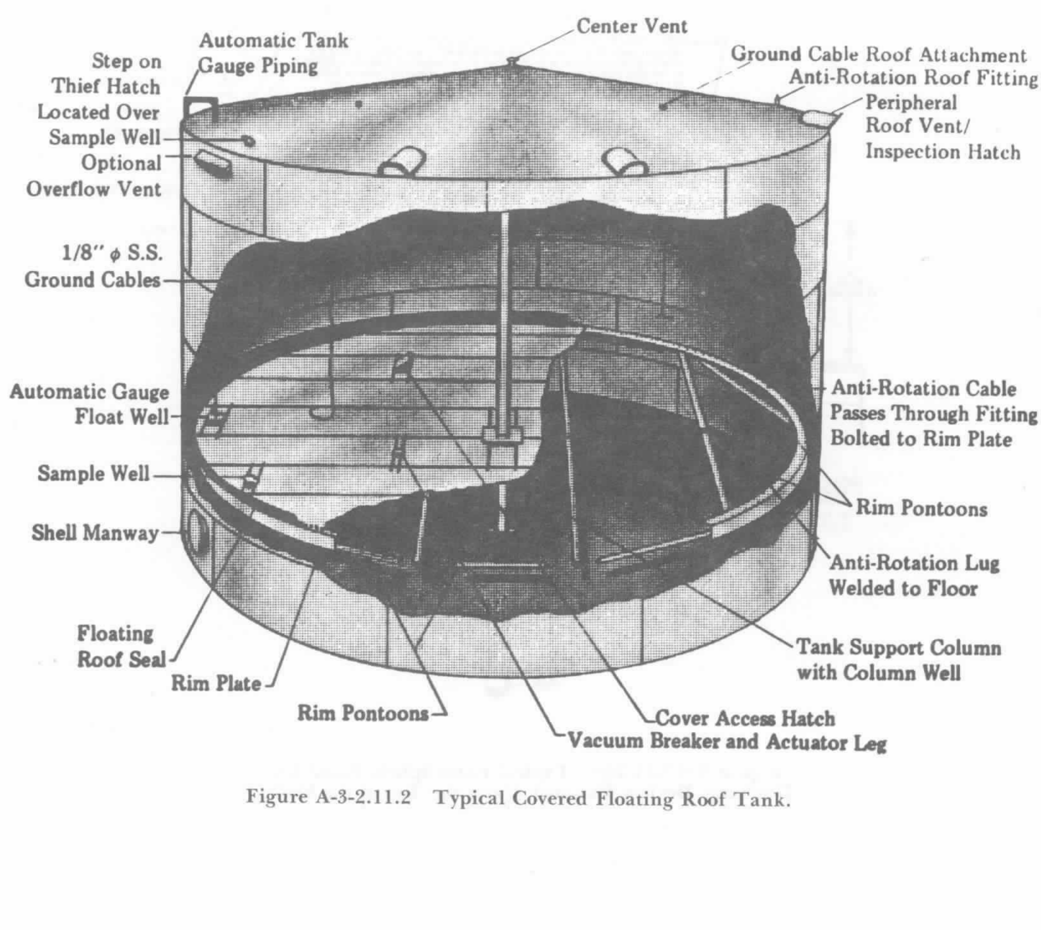


Figure A-3-2.11.2 Typical Covered Floating Roof Tank.

A-3-3.1 Examples of Foam Spray Systems.

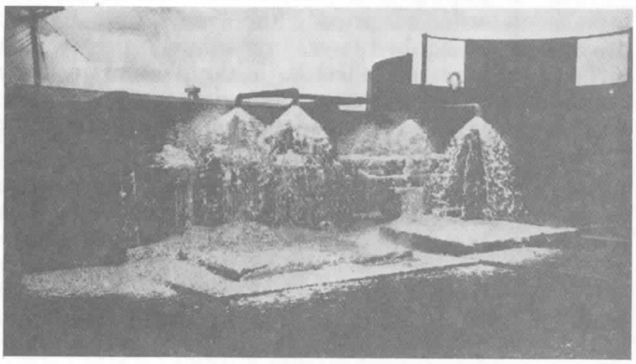


Figure A-3-3.1(a) Overhead Air Foam Spray.

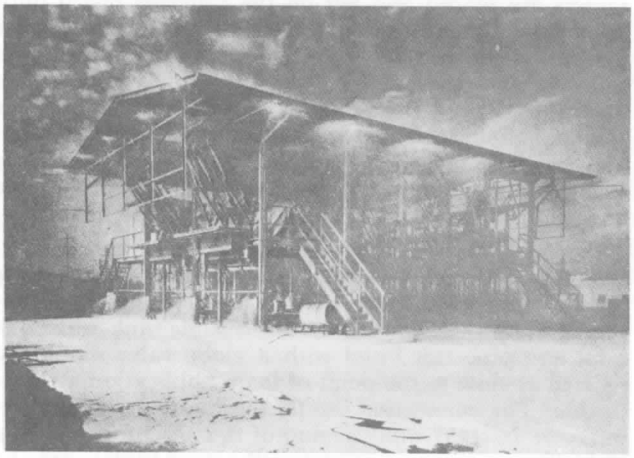


Figure A-3-3.1(b) Truck Loading Rack Foam Spray System.

A-5-2 Acceptance Tests.

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

1. All foam-producing devices are operating at "system design" pressure and at "system design" foam solution concentration.

2. The laboratory-type tests have been conducted, where necessary, to determine that water quality and foam liquid are compatible.

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

1. Static water pressure.

2. Stabilized flowing water pressure at both the control valve and a remote reference point in the system.

3. Rate of consumption of foam concentrate.

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

A-5-2.4 Introduction. With the greatly expanding uses of foam in aircraft fire fighting and in foam-water sprinkler systems, in addition to those applications previously covered in this standard, there has arisen the need for a standardized laboratory procedure for analyzing and expressing the significant physical properties of mechanical foam as related to fire fighting capability. The equipment and techniques used have been selected to assist in the development of system components, nozzles, and foaming agents.

The numerical values obtained by these tests generally enable a characterization of the foam. Only by describing results obtained on a standardized basis will it be possible to describe the optimum foam for the various operating conditions such as petroleum storage tanks, foam-water sprinklers, dip tanks, etc. Attempts have been made to select these foam types; however, because of the limited amount of data taken under a limited number of conditions, the conclusion must be accepted with understandable reservations.

A-6-1.1.1 Procedures for Measuring Expansion and Drainage Rates of Foams.

Foam Sampling. The object of foam sampling is to obtain a sample of foam typical of that to be applied to the burning surface under anticipated fire conditions. Inasmuch as 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 has been designed chiefly to facilitate the rapid collection of foam from low-density patterns; in the interest of standardization it is also used for all sampling except where pressure-produced foam samples are being drawn from a line tap. A backboard is inclined at a 45 degree angle suitable for use with vertical streams falling from overhead applicators as well as horizontally directed streams. [*See Figures A-6-1.1.1(a) and A-6-1.1.1(b).*]

The standard container is 7.9 in. (20 cm) deep and 3.9 in. (10 cm) inside diameter (1600 mL) preferably made of 1/16-in. (1.6 mm) thick aluminum or brass. The bottom is sloped to the center where a 1/4-in. (6.4-mm) drain fitted with a 1/4-in. valve is provided to draw off the foam solution. [*See Figure A-6-1.1.1(b).*]

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

Initially, the collector should be placed at the proper distance from the nozzle so as to be 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

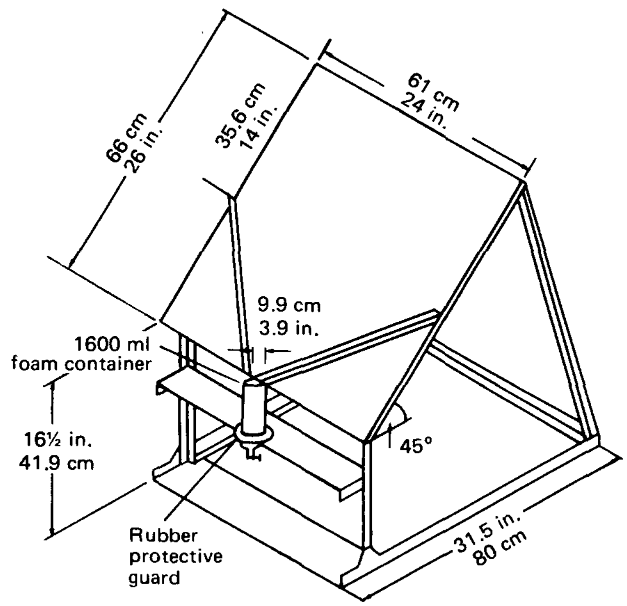


Figure A-6-1.1.1(a) Foam Sample Collector.

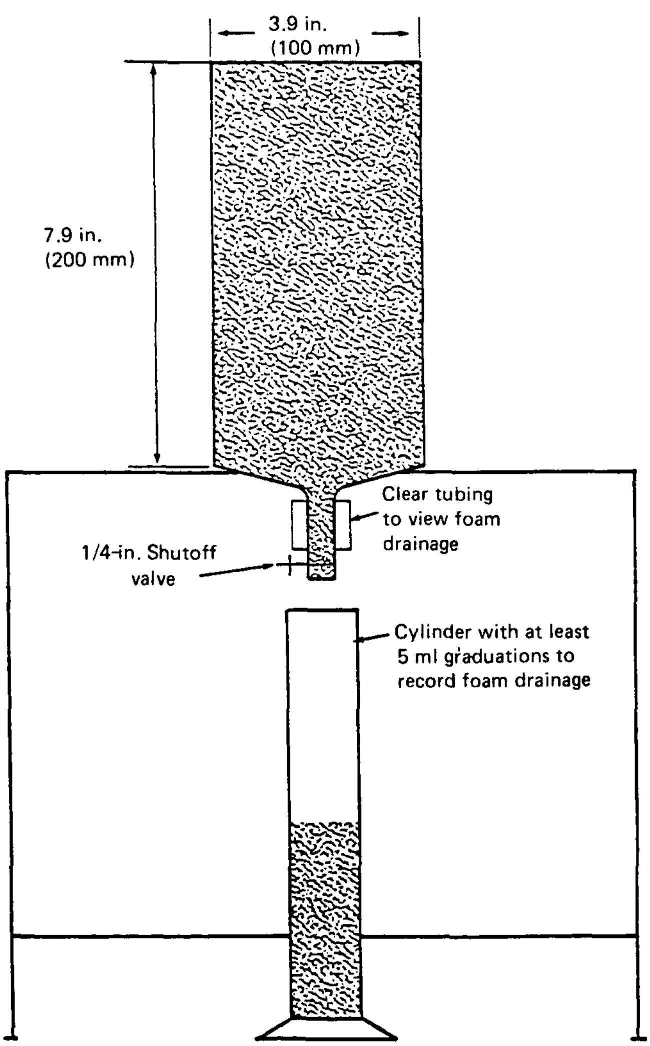


Figure A-6-1.1.1(b).

the sample containers, usually in a matter of 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 are 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.

Overhead Devices. (Here 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 shall 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.

Pressure Foam. (Here it is presumed that foam is flowing under pressure from a foam pump or high-pressure aspirator toward an inaccessible tank outlet.) A 1-in. size pipe tap fitted with a globe valve should be located as close to the point of foam application as practicable. The connection should terminate in an approximate 18-in. (457-mm) section of flexible rubber tubing to facilitate filling the sample container. In drawing the sample, the valve should be opened as wide as possible without causing excessive splashing and air entrainment in the container. Care must 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.

Foam Chambers. In some instances where the foam makers are integral with the foam chambers on the top ring of a tank, none of the above methods of sampling may be workable. In this case it will be necessary to improvise as well as possible, 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 must 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 the normal rates of application, it may take a few minutes to build up the several inches in depth required and this time may definitely 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 Moëller tube installation, it would be advisable to sample right alongside the tube as foam oozes out in good 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.

Foam Testing. The foam samples, as obtained in the above described procedures, 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, the taking of one sample will be acceptable.

Apparatus Required

2 — 1600 mL sample containers

1 — foam collector board

1 — balance (triple beam balance, 2610 g capacity)

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

$$\frac{1600}{\text{(full weight minus empty weight)}} = \text{expansion}$$

(All weights to be expressed in grams.)

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

Apparatus Required

2 — Stopwatches

1 — Sample stand

4 — 100-mL-capacity plastic graduates

Procedure. This test is performed on the same sample as used in the expansion determination. Dividing the net weight of the foam sample by 4 will give the 25 percent volume, in mL, of solution contained in the foam. To find the time required for this volume to drain out, the sample container should be placed on a stand, as indicated, and at regular suitable intervals, the accumulated solution in the bottom of the container should be drawn off into a graduate. The time intervals at which the accumulated solution is drawn off are dependent on the foam expansion. For foams of expansion 4 to 10, 30-second intervals should be used, and for foams of expansion 10 and above, 4-minute intervals should be used because of the slower drainage rate of foams of this type. In this way, a time-drainage volume relationship is obtained and after the 25 percent volume has been exceeded, the 25 percent drainage time is interpolated from the data. The following example shows how this is done:

The net weight of the foam sample has been found to be 180 grams. Since 1 gram of foam solution occupies a volume of essentially 1 mL, the total volume of foam solution contained in the given sample is 180 mL.

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

$$25\% \text{ Volume} = \frac{180}{4} = 45 \text{ mL}$$

Then if the time-solution volume data has been recorded as follows:

Time — Min.	Drained Solution Volume — mL
0	0
0.5	10
1.0	20
1.5	30
2.0	40
2.5	50
3.0	60

It is seen that the 25 percent volume of 45 mL lies within the 2.0- and 2.5-minute period. The proper increment to add to the lower value of 2.0 minutes is determined by interpolation of the data:

$$\frac{\text{45 mL (The 25\% Vol.)} - \text{40 mL (The 2.0 min Vol.)}}{\text{50 mL (The 2.5 min. Vol.)} - \text{40 mL (The 2.0 min Vol.)}}$$

$$= \frac{5}{10} = \frac{1}{2}$$

This means it is halfway between 2.0 and 2.5 minutes, or 2.25 minutes, which is rounded off to 2.3 minutes.

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

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

A-6-1.1.2 Method for Determination of Film-Forming Capability. In this test, a quantity of foam is placed on the surface of cyclohexane (a hydrocarbon liquid). The foam is swept from the surface by insertion of a conical screen, and the exposed fuel surface is tested for the presence of an aqueous film by probing with a flame. If film is present, the fuel will not sustain ignition; in the absence of film, sustained ignition will occur.