NFPA

11

FOAM EXTINGUISHING SYSTEMS 1978

NFPA®

NATIONAL FIRE PROTECTION ASSOCIATION
470 Atlantic Avenue, Boston, MA 02210

4M-7-78-FP
Printed in U.S.A.

NOTICE

All questions or other communications relating to this document should be sent only to NFPA Headquarters, addressed to the attention of the Committee responsible for the document.

For information on obtaining Formal Interpretations of the document, proposing Tentative Interim Amendments, proposing amendments for Committee consideration, and appeals on matters relating to the content of the document, write to the Assistant Vice President–Standards, National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02210.

Statement on NFPA Procedures

This material has been developed under the published procedures of the National Fire Protection Association, which are designed to assure the appointment of technically competent Committees having balanced representation. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accepts any liability resulting from compliance or noncompliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text.

NFPA has no power or authority to police or enforce compliance with the contents of this document and any certification of products stating compliance with requirements of this document is made at the peril of the certifier.

See Official NFPA Definitions at the back of this pamphlet.

Standard for

Foam Extinguishing Systems

NFPA 11–1978

1978 Edition of NFPA 11

This document was prepared by the Technical Committee on Foam and this present edition was adopted by the Association on May 18, 1978, at its Annual Meeting in Anaheim, California. It was released by the Standards Council for publication on June 6, 1978.

Changes other than editorial are denoted by a vertical line in the margin of the pages in which they appear.

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 edition of 1976 and prior editions adopted in 1922, 1926, 1931, 1936, 1942, 1950, 1954, 1959, 1960, 1963, 1969, 1970, 1972, 1973, 1974, and 1975.

The 1976 edition of this standard was approved by the American National Standard Institute as an American National Standard and designated Z286.1 — 1976. The 1978 edition will be submitted for similar approval.

Technical Committee on Foam

Norman R. Lockwood, *Chairman*
Mobil Research & Development Center
Engineering Department
(rep. American Petroleum Institute)
Alternate to R. F. Murphy

Herb E. Wolff, *Secretary*
Reliance Insurance Companies
(rep. American Insurance Association)

Wayne E. Ault, Rolf Jensen & Associates, Inc.

C. F. Averill, National Automatic Sprinkler & Fire Control Assn.

Francis X. Bender, NFPA Industrial Fire Protection Assn.

William G. Boyce, U.S. Coast Guard

R. R. Burford, 3M Company

William M. Carey, Underwriters Laboratories Inc.

J. R. Corcoran, Edison Electric Corporation

MacDonald Curless, Fire Protection Engineers

F. L. Deacon, American Mutual Insurance Alliance

John A. Krembs, M & M Protection Consultants

Arthur Lagadinos, Insurance Services Office, NE Region

Jack P. McLaughlin, Union Carbide Corporation

D. N. Meldrum, National Foam Systems, Inc.

Robert C. Merritt, Factory Mutual Research Corporation

Richard F. Murphy, American Petroleum Institute

H. B. Peterson, U. S. Naval Research Laboratory

L. E. Rivkind, The Mearl Corporation

Eugene Stauffer, Fire Equipment Manufacturers Assn.

Sturgis L. Stenz, Lorcon Foam, Inc.

Dr. Richard L. Tuve, Johns Hopkins University

Ray H. Vliet, NFPA Fire Service Section

Laurence D. Watrous, Brown & Root, Inc.

Alternates

Layard E. Campbell, National Automatic Sprinkler and Fire Control Association (Alternate to C. F. Averill)

Edward J. O'Donoghue, Industrial Risk Insurers (Alternate to R. H. Brown)

C. E. Saunders, American Mutual Insurance Alliance (Alternate to F. L. Deacon)

Miles R. Suchomel, Underwriters Laboratories Inc. (Alternate to William M. Carey)

G. A. Toyek, Insurance Services Office (Alternate to A. Lagadinos)

Klaus Wahle, U. S. Coast Guard (Alternate to W. G. Boyce)

Kenneth A. Zuber, Fire Equipment Manufacturers Assn. (Alternate to E. Stauffer)

Nonvoting

Desmond Hird, Angus Fire Armour
Division of George Angus Co., Ltd.

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

CONTENTS

Standard for

Foam Extinguishing Systems

NFPA 11–1978

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 tanks or processing areas. Foam solution for these hazards may be supplied by fixed piped systems or portable foam generating systems. Foam may be applied by foam discharge outlets, which allow it to fall gently on the surface of the burning fuel, or it may be introduced by other means. Foam may also be applied to these hazards 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. For systems required to meet both foam and water design criteria, refer to NFPA 16, *Standard for the Installation of Foam-Water Sprinkler Systems and Foam-Water Spray Systems.* (*See Appendix B.*)

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 as a dispersed pattern. Standards for aircraft crash trucks may be found in detail in NFPA 414, *Standard for Aircraft Rescue and Fire Fighting Vehicles.* (*See Appendix B.*)

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.

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 reflectivity, cooling effect, and insulating characteristic. In the case of certain combustible surfaces these characteristics may prevent ignition.

Chapter 1

General Requirements and Information

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

1-1 Scope. This standard covers the characteristics of foam-producing materials and the requirements for design, installation, operation and maintenance of equipment and systems. 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. Methods of testing systems are also included. This standard does not include requirements for synthetic and high expansion foam systems. (*See 1-4.3.3.*)

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 foam fire extinguishing systems, either portable or fixed for interior or exterior hazards.

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 (litre), outside of but recognized by SI, is commonly used in international fire protection. The units are listed in Table 1-3 with conversion factors.

Table 1-3

Name of Unit	Unit Symbol	Conversion Factor
litre	l	1 gal = 3.785 l
litre per minute per square metre	$l/\text{min}\cdot\text{m}^2$	1 gpm/ft^2 = 40.746 $l/\text{min}\cdot\text{m}^2$
cubic decimetre	dm^3	1 gal = 3.785 dm^3
pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 10^5 Pa
kilopascal	kPa	1 psi = 6.895 kPa

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

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

1-3.2 The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

1-4 Definitions.

1-4.1 Flammable and Combustible Liquids. Flammable liquids shall mean any liquid having a flashpoint below 100°F (37.8°C) and having a vapor pressure not exceeding 40 lb/sq in. (276 kPa) (absolute) at 100°F (37.8°C). Flammable liquids shall be subdivided as follows:

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

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

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

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

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

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

1-4.2 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 and clinging to vertical or horizontal surfaces. 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 due to 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.

1-4.2.1 Air Foam or Mechanical Foam is made by mixing air into a water solution containing a foam concentrate by means of suitably designed equipment. One gallon (3.8 *l*) of foam solution will produce about 8 gallons (30.3 *l*) of air foam. This figure is representative of playpipe performance and delivery from fixed air foam makers of the low back pressure type. Foam production from high back pressure type foam makers is 4 gallons (15.1 *l*) of air foam per gallon (3.8 *l*) of solution or less, varying with the back pressure imposed.

1-4.2.2 Chemical Foam is made by the reaction of an alkaline salt solution (usually bicarbonate of soda) and an acid salt solution (usually aluminum sulphate) to form a gas (carbon dioxide) in the presence of a foaming agent which 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.

1-4.3 Air Foam Concentrate. Air foam concentrate is a concentrated liquid foaming agent as received from the manufacturer.

1-4.3.1 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 upon the type.

1-4.3.2 Fluoroprotein-Foam Concentrates are 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.

1-4.3.3 Synthetic Foam Concentrates are based on foaming agents other than hydrolysed proteins. They include:

(a) **Aqueous Film Forming Foam (AFFF) Concentrates** are based on fluorinated surfactants plus foam stabilizers and are 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. Guidance for use of these materials is given in NFPA 11B, *Synthetic Foam and Combined Agent Systems.* (*See Appendix B.*)

(b) **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 100:1 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, *High Expansion Foam Systems.* (*See Appendix B.*)

(c) **Other Synthetic Concentrates** are 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 application to spill fires within the scope of their listings by nationally recognized laboratories. Guidance for use of the materials is given in NFPA 11B, *Synthetic Foam and Combined Agent Systems.* (*See Appendix B.*)

1-4.3.4 Special "Alcohol Type" Foam Concentrates form a foam which has an insoluble barrier in the bubble structure which resists breakdown at the interface of the fuel and foam blanket. They are used for fighting fires in water soluble and certain flammable or combustible liquids and solvents which are destructive to regular foams.

1-4.3.5 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 and AFFF concentrates may be applied to a fire in sequence or simultaneously.

1-4.4 Foam Solution. Foam solution is a homogeneous mixture of water and foam concentrate in the proper proportion.

1-4.5 Foam Solution Proportioning Method. Foam solution is produced by continuous introduction of foam concentrate at the recommended ratio to water flow.

1-4.6 Foam Solution Premix Method. Foam solution is produced by premixing foam concentrate directly into the water in a storage tank.

1-5 Air Foam.

1-5.1 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:

*1-5.1.1 **Foam Nozzle Inductor.** A suitably designed venturi with "pick-up 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.

*1-5.1.2 **In-line Inductor.** A venturi inductor 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.

*1-5.1.3 **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 by-pass between the pump suction and the pump discharge.

*1-5.1.4 **Metered Proportioning.** A separate foam concentrate pump is used to inject foam concentrate into the water stream. Orifices or venturis or both control or measure the proportion of water to foam concentrate. Either manual or automatic adjustment of foam concentrate injection by pressure or flow control 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.

*1-5.1.5 **Pressure Proportioning Tank.** A suitable method is provided for displacing foam concentrate from a closed tank by water (with or without a diaphragm separator), using water flow through a venturi orifice.

*1-5.1.6 **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.

1-5.2 Air Foam Generating Methods. The methods of generation of air foam recognized in this standard include:

*1-5.2.1 **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.

***1-5.2.2 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.

1-5.2.3 Foam Pump. A positive-displacement type pump is connected to a supply of foam solution. Part of the intake of this pump is open to the atmosphere so that when it is operated at the proper speed the air and solution are intimately mixed to form foam under pressure.

1-5.3 Storage of Air Foam Concentrates. In order to insure the correct operation of any foam-producing system, the chemical and physical characteristics of the materials comprising the system are taken into consideration in its 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.

1-5.3.1 Foam concentrate may be stored in the containers in which it is transported or it may be transferred to large bulk storage tanks depending on the requirements of the system. These foam concentrates are subject to freezing and deterioration by prolonged storage at high temperatures. For ready use they shall be stored within the listed temperature limitations. 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.

1-6 Chemical Foam. Chemical foam is the oldest form of fire fighting foam (ca. 1903) and is no longer in general use. The excessive maintenance needed to insure reliability and excessive manpower necessary during an emergency have made this type of foam less desirable than air foam.

***1-6.1 Chemical Foam Powders.** These are dry mixtures of powders used to generate chemical foam by their interaction when mixed with water, at or near the point where the chemical foam is needed. There are three types of chemical foam powders: *Dual powder charges*, where the alkaline salt portion of the chemical foam powder is packed separately from the acidic salt portion of the charge and the containers are marked "A" and "B" powders; *Single powder charges*, where a single blend of all the chemical foam powders needed to produce chemical foam is in a single container; *Special "alcohol type" single powder charges*, where a single blend of specially formulated chemical foam powder is packaged for use on fires involving water-miscible solvents such as alcohol, etc. All types are packaged in dry moisture-proof containers. Since chemical foam powders are no longer in general use, replacement materials may not be available from recognized vendors.

1-6.2 Chemical Foam Generating Methods. The methods of generation of chemical foam include:

1-6.2.1 Continuous Foam Generators. An open funnel-shaped container (or dual containers) is positioned at the terminus of a water supply. It is so designed that when dry foam powder (or dual powders) is fed into it the water stream picks up the necessary amount for interaction to produce foam. Some types of continuous generators consist of separate containers for the acid and alkaline salts and the two solutions formed are kept separate until admixture in the system beyond the point of solution in water. The foam formed in either of the above systems is conducted in either piping or hoses to the hazard being protected.

1-6.2.2 Stored Solution Systems. This is a "wet system" and employs the necessary reacting chemicals as separate water solutions of alkaline salts and acidic salts made and stored in containers separately piped to a central mixing point where foam is generated by their interaction. The resulting foam is piped to the hazard being protected.

***1-6.3 Storage of Chemical Foam Materials.** Special design and handling are needed when storing chemical foam materials.

1-7 Use and Limitations of Foams. The uses of foams within the limits of this standard are listed below.

Characteristics and uses of other foams may be found in NFPA 11A, *High Expansion Foam Systems*, and NFPA 11B, *Synthetic Foam and Combined Agent Systems*. (*See Appendix B.*)

1-7.1 The uses of foam are as follows:

(a) The principal use of foams is the extinguishment of burning liquids lighter than water.

(b) Ignition and fire may be prevented by applying foam blankets to spills or other hazardous areas.

(c) Foams may also be used to insulate and protect exposures from radiant heat. They also act to prevent ignition of open areas of flammable liquids if spread completely over an exposed surface. It is well to remember, however, that foam breakdown can render such a foam protective coating of no value to the fire fighter and frequent renewal may be necessary.

(d) Because of the water content, foams may be used to extinguish surface fires in ordinary combustible materials such as wood, paper, rags, etc.

***1-7.2** The limitations of foam are as follows:

(a) Foams are not suitable extinguishing agents for fires involving gases, liquefied gases with boiling points below ambient temperatures such as butane, butadiene, propane, etc., or cryogenic liquids.

*(b) Flowing liquid fires, such as overhead tank leakage or pressure leaks, are not readily extinguishable with foams.

(c) Foams shall not be used to fight fires in materials which react violently with water, such as metallic sodium and metallic potassium, etc. In certain magnesium fires, foams may be judiciously applied to help restrict burning and cool residual metal.

(d) Foam is a conductor and shall not be used on energized electrical equipment fires.

(e) Judgment must be used in applying foams to hot oils, burning asphalts or burning liquids which are above the boiling point of water. Although the comparatively low water content of foams can beneficially cool such fuels at a slow rate it can also cause violent frothing and "slop-over" of the contents of the tank.

*(f) Certain wetting agents and some dry chemical powders may be incompatible with foams. If they are used simultaneously, an instantaneous breakdown of the foam blanket may occur.

(g) Protein and fluoroprotein foams are not suitable for water soluble or polar solvent liquids. Special foams designed for these materials are available.

(h) The manufacturer of the concentrate shall be consulted regarding storage life when the concentrate is to be used in a premix solution.

1-7.3 Consideration shall be given to potential contamination of water supplies, treating systems, and effluent by foam or solution runoff.

1-7.4 The manufacturer of components, authorities having jurisdiction and listing agencies shall recognize that 10-minute or longer delays between fire occurrence and application of foam to the burning surface are common.

1-7.5 Personnel shall not enter fuel covered areas or areas where fuel is suspected unless the entire area is covered with an intact, visible blanket of foam.

1-7.6 Prolonged free burning or weather conditions, such as heavy winds, may have an adverse effect on foam performance.

1-7.7 Simultaneous use of water streams with foam discharge or on foam covered areas will break down the foam blanket and shall be avoided.

1-8 Specifications and Plans.

1-8.1 The specifications shall designate the authority having jurisdiction and indicate whether submittal of plans is required. They shall state that the installation shall conform to this standard and meet the approval of the authority having jurisdiction. They shall include the specific tests that will be required to meet the approval of the authority having jurisdiction, and indicate how cost of testing is to be borne.

1-8.2 Plans. Where plans are required, their preparation 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.

1-8.2.1 Plans shall contain or be accompanied by the following information, when applicable, to enable the authority having jurisdiction to evaluate the suitability of the system:

(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, Installation of Sprinkler Systems, for hydraulic calculation procedures.*) (*See Appendix B.*)

(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.

1-8.3 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.

1-9 Water Supplies.

1-9.1 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 used without prior consultation with the foam concentrate supplier.

1-9.2 Quantity. The water supply shall be adequate in quantity to supply all the devices that may be used simultaneously. This includes not only the volume required for the foam apparatus but also water which may be used in other fire fighting operations, in addition to the normal plant requirements.

1-9.3 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.

1-9.4 Temperature. Optimum foam production is obtained using water at temperature between 40°F (4.4°C) and 100°F (37.8°C). Higher or lower water temperatures may reduce foam efficiency.

***1-9.5 System Design.** The water system shall be designed and installed in accordance with recognized standards for such extinguishing systems. Where solids of sufficient size to obstruct openings in the foam equipment may be present, strainers shall be provided. Hydrants furnishing the water supply for portable foam equipment shall be provided in sufficient number and be located as required by the authority having jurisdiction.

1-10 Air Foam System Design.

1-10.1 Suitable listed or approved equipment and listed concentrates of the type described earlier in this standard shall be furnished in size and type in accordance with the detailed foam application requirements for the hazard to be protected as required by the authority having jurisdiction. This equipment shall include the necessary prime movers, foam concentrate proportioners and storage tanks, foam generators and foam piping and discharge devices.

1-10.1.1 Foam systems shall be designed so that all components having moving parts can be periodically tested without discharging foam onto the hazard.

1-10.2 Discharge Outlets. Discharge outlets shall be designed and located to permit the distribution of the foam over the area to be protected. Discharge outlets may be in combination with mixing devices or may be separate devices.

1-10.3 System Piping.

1-10.3.1 Pipe Materials. Pipe within the hazard area shall be steel, suitable for the pressure 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, piping shall be protected against corrosion.

1-10.3.2 Valves. All valves shall be listed for fire protection use. 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. Automatic control valves, shutoff valves and strainers of approved types may be cast iron if outside the fire area, but shall be steel if within the fire area.

1-10.3.3 Fittings. All pipe fittings shall be American Standard for the pressure class involved but not less than 125 lb standard. Iron fittings shall be malleable in dry sections of the piping exposed to possible fire. All fittings subject to stress in self-supporting systems shall be steel or malleable iron.

1-10.3.4 Strainers. Where solids of sufficient size to obstruct openings in foam equipment may be present, strainers shall be used.

1-10.3.5 Installation. Piping shall be so arranged as to reduce friction to a reasonable minimum. All piping shall be securely supported. All foam distribution piping shall be arranged to drain and shall have a pitch toward drain of ½ inch in each 10 feet (4.2 mm/m). Foam system piping shall be normally empty.

1-10.3.6 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. The water pressure of the inlet to air foam makers should preferably be not less than 50 psig (345 kPa gauge). Operation is, however, possible with water pressure as low as 30 psig (207 kPa gauge). 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.*) (*See Appendix B.*) For friction losses in piping carrying foam concentrate see NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, Section 4064. (*See Appendix B.*) For friction losses in piping carrying foam, see A-3-6.2. For purpose of computing friction loss in 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

1-10.3.7 Flushing after 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, in order to remove foreign materials which may have entered during installation. 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 and the available water supply. The flow shall be continued for a sufficient time to insure 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, cleanliness of pipe interiors shall be carefully examined visually during installation.

1-10.3.8 Flushing after Use. Provision shall be made in the design to permit flushing of normally empty foam concentrate and solution piping with clean water after use.

1-10.4 Storage of Foam Concentrate Equipment.

1-10.4.1 Storage Facilities. Storage of foam concentrates and equipment shall be in an accessible location not exposed by the hazard they protect. If housed, they shall be in a noncombustible structure.

1-10.4.2 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.

1-10.4.3 Off-Premises Storage. 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.

*__1-11 Acceptance Tests.__ The completed system shall be inspected and tested by qualified personnel to determine that it is properly installed and will function as intended.

1-11.1 Inspection and Visual Examination. Foam systems shall be examined visually to determine that they have been properly installed. They shall be inspected for such items as conformity with installation plans, continuity of piping, removal of temporary blinds, accessibility of valves, controls and gauges, and proper installation of vapor seals, where applicable. Devices shall be checked for proper identification and operating instructions.

1-11.2 Pressure Tests. All piping, except that handling expanded foam for other than subsurface application, shall be subjected to a two-hour hydrostatic pressure test at 200 psig (1379 kPa gauge) or 50 psi (345 kPa) in excess of the maximum pressure anticipated, whichever is greater, in conformity with NFPA 13, *Installation of Sprinkler Systems*. (*See Appendix B.*) All normally dry horizontal piping shall be inspected for drainage pitch.

1-11.3 Operating Tests. Before acceptance, all operating devices and equipment shall be tested for proper function.

1-11.4 Discharge Tests. Where conditions permit, flow tests shall be conducted to ensure that the hazard is fully protected in conformance with the design specification, and to determine the flow pressures, actual discharge capacity, consumption rate of foam-producing materials, manpower requirements and other operating characteristics. The foam discharged shall be visually inspected to ensure that it is satisfactory for the purpose intended.

1-11.5 System Restoration. After completion of acceptance tests the system shall be flushed and restored to operational condition.

1-12 Periodic Inspection, Testing, Maintenance, Operating and Training. All systems shall be thoroughly inspected by a competent inspector at regular intervals, at least annually, to ensure that they will remain in full operating condition. Regular service contracts with the manufacturer or installer are generally available.

1-12.1 Foam-Producing Equipment. Proportioning devices, their accessory equipment and foam makers shall be inspected.

1-12.2 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 five years.

1-12.3 Strainers. Strainers shall be inspected and cleaned after each use and flow test.

1-12.4 Detection and Actuation Equipment. Control valves including all automatic and manual actuating devices shall be tested at regular intervals.

1-12.5 Air Foam Concentrates. Periodic inspection shall be made of air 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.

1-12.6 Operating Instructions and Training. Operating and maintenance instructions and layouts shall be posted at control equipment and at fire headquarters. 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 2 Fixed Foam Extinguishing Systems for Indoor Flammable Liquid Hazards

2-1 General.

2-1.1 Object. This section relates to foam fire extinguishing systems which are intended as the primary protection for specific hazards located in rooms and buildings, or general protection for the contents of the room or building and may or may not include the structure.

NOTE: This section does not cover foam-water sprinklers or foam-water spray systems (*see NFPA 16, Standard for the Installation of Foam-Water Sprinkler Systems and Foam-Water Spray Systems, or NFPA 11A, Standard for High Expansion Foam Systems*). (*See Appendix B.*)

2-1.1.1 These systems are particularly applicable to the indoor storage and handling of flammable and combustible liquids. Typical applications would be in storage areas, areas subject to large spills, process equipment, pump rooms, open tanks, such as dip tanks, quench tanks, mixing tanks, etc., which may be found in chemical plants, solvent extraction plants, distillation plants, and refineries.

2-1.2 Definitions.

2-1.2.1 Spray Foam System. A spray foam system is a special system pipe-connected to a source of foam producing solution and is equipped with spray nozzles for foam discharge and distribution over the area to be protected.

2-1.2.2 Discharge Devices. Discharge devices generally fall into two categories: those producing foam in a spray or a dispersed pattern, and those producing foam in a compact low velocity stream.

(a) Devices which discharge foam in a spray pattern terminate in a deflector or screen which dispenses the foam.

(b) Devices which discharge foam as a compact low velocity stream may or may not have deflectors or stream directors included as an integral part of the device. These devices may take such forms as open pipe fittings, directional flow nozzles, or small foam-making chambers with open outlets.

(c) These discharge devices in approved forms are available in a number of patterns with variations in discharge capacity. Such devices may or may not have the foam maker included as an integral part.

2-2 Limitations. Only foams listed for the purpose shall be used on water soluble solvents in depth exceeding one inch (25 mm), through spray foam discharge devices.

Exception: Alcohol type foams may be used when the system is specially designed for this application and approved by the authority having jurisdiction.

NOTE: For general limitations see Section 1-7.

2-3 Foam Quality.

2-3.1 Foam delivered from spray foam systems shall quickly form a cohesive foam blanket and spread rapidly around obstructions. Foams discharged from such systems, and meeting these requirements, have exhibited "expansions" ranging from 4 to 8; and "25 percent drainage time" values, ranging from 0.30 minute to 1 minute.

2-3.2 Foam discharge from devices producing a compact low velocity stream shall have characteristics within the limits shown in Figure A-7-1.1(g).

2-4 System Description.

2-4.1 A system consists of detection devices, an adequate water supply, supply of foam producing materials, suitable proportioning equipment, a proper piping system, foam makers, and discharge devices designed to adequately distribute the foam over the hazard.

2-4.1.1 These systems are of the open outlet deluge type in which foam discharges from all outlets at the same time, covering the entire hazard within the confines of the system.

2-4.1.2 Self-contained systems are those in which all components and ingredients, including water, are contained within the systems. Such systems usually have a water supply tank that is pressurized by air or compressed gas, and the release of this pressure into the system puts it in operation. These systems may also be pressurized by the chemical reaction of solutions that are mixed at the time of system operation.

2-4.2 Automatic Operation.

2-4.2.1 In an automatic system there are fire detection devices which may be any of a number of listed detectors. These detectors usually activate the system by operating the water control valve or other actuating device. All other equipment is 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.

2-4.2.2 Automatic detection equipment, whether pneumatic, hydraulic or electric, shall be provided with complete 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.

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

2-4.2.3 Automatic detection equipment of electric type and any auxiliary equipment of electric type, 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, thereof. (*See Appendix B.*)

2-4.2.4 In some special cases it may be desirable to arrange the system to shut off automatically after a predetermined operating time. This feature would be subject to approval of the authorities having jurisdiction.

2-5 System Design.

2-5.1 These systems shall be designed for automatic operation, supplemented by auxiliary manual tripping means.

2-5.2 In systems designed for general area protection of rooms or buildings where spray foam devices are used, the discharge outlets should generally be located as high as possible in the area, and spaced in accordance with their discharge patterns so that the system covers the entire protected area.

2-5.2.1 When floor type outlets are used, they shall be located and spaced so the foam will flow as rapidly as possible over the area.

2-5.3 Open tanks of flammable liquids may be protected by "tank side" nozzles discharging foam at low velocity directly on the liquid surfaces, or by means of "foam spray" nozzles mounted above the tank.

***2-5.4** Protection for specific pieces of equipment may be provided by overhead application or by directional discharge devices directed at the equipment. Where the basic objective of the system is extinguishing a spill fire on the floor, enveloping the equipment in the foam discharge has the added advantage of providing an insulating effect to protect the equipment from heat exposure while the fire is being extinguished.

2-5.5 In some hazard arrangements it may be desirable to design systems utilizing combinations of the system designs described in 2-5.2, 2-5.3 and 2-5.4.

2-5.6 Where air-foam concentrate lines to the protective-system injection points are run underground or where they run aboveground for more than 50 feet (15.2 m), air-foam liquid concentrate in these lines shall be maintained under pressure to assure prompt foam application and to provide a means of checking on the tightness of the system.

Pressure may be maintained by a small auxiliary pump, or by other suitable means.

***2-5.7** Equipment items, such as storage tanks, proportioners, pumps, and control valves shall be installed where they will be accessible, especially during a fire emergency in the protected area and where there will be no exposure from the protected hazard. Automatically controlled valves shall be as close to the hazard protected as accessibility permits so that a minimum of piping is required between the automatic-control valve and the discharge devices.

2-5.8 Size of System. Systems may be used to protect one or more hazards or groups of hazards using the same supply of foam concentrate and water.

2-5.8.1 The size of a single system shall be kept as small as practicable, giving consideration to water supplies and other factors affecting the reliability of the protection.

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

2-6 Rate of Application.

2-6.1 For Liquid Hydrocarbons.

2-6.1.1 For area protection, the discharge of foam outlets shall provide a solution rate of at least 0.16 gpm per square foot (6.5 $l/\text{min}\cdot\text{m}^2$) of the area protected.

2-6.1.2 Where there are intervening horizontal surfaces that would collect foam, such as large tanks, mezzanines or decks, etc., these shall be taken into consideration in arriving at the design discharge rate.

2-6.1.3 Where open top tanks are protected by discharge outlets located on the tank, the rate of application shall be 0.16 gpm per square foot (6.5 $l/\text{min}\cdot\text{m}^2$) of liquid surface.

2-6.1.4 When small open tanks are protected by spray foam system, close attention shall be given to the percentage of the system discharge which actually enters the tank, to assure that the required application rate is being achieved.

2-6.2 Water soluble and certain flammable and combustible liquids and polar solvents which are destructive to regular foams require the use of "alcohol" type foams. Systems using these foams require special engineering consideration and may require that higher application rates be used. In all cases, the manufacturer of the foam concentrate and the foam-making equipment shall be consulted as to the limitations and for recommendations based on listings or specific fire tests.

2-7 Operating Time.

2-7.1 For Area Protection.

2-7.1.1 The duration of foam discharge shall be a minimum of 10 minutes. When a system has been designed to have a delivery rate higher than that specified in Section 2-6, a proportionate reduction in the discharge time may be made except that it shall not be less than seven minutes.

2-7.2 For Tanks of Less Than 400 Square Feet (37.2 m^2) Liquid Surface.

2-7.2.1 For overhead spray foam discharge outlets, the duration of foam discharge shall be a minimum of five minutes.

2-7.2.2 For tank mounted foam discharge outlets, the duration of foam discharge shall be a minimum of three minutes.

2-7.2.3 Where the normal freeboard is such that if the discharge time would cause a significant quantity of foam to overflow and be wasted, the authority having jurisdiction shall be consulted.

2-7.2.4 Suitable overflow facilities shall be provided to maintain a constant freeboard of not less than 6 inches (152 mm). For additional information see NFPA 34, *Standard for Dip Tanks Containing Flammable or Combustible Liquids*. (*See Appendix B.*)

2-7.3 For tanks of 400 square feet (37.2 m^2) and larger liquid surface area, apply the operating time rules for outdoor tanks.

2-8 Supply of Foam-producing Materials.

2-8.1 Total supply of foam-producing materials shall be the sum of the quantities specified in 2-8.2 and 2-8.3.

2-8.2 There shall be a quantity of foam-producing materials sufficient to supply the system in accordance with Sections 2-6 and 2-7.

2-8.3 Reserve Supply. There shall be a reserve supply of foam-producing materials in accordance with 1-10.4.2.

2-9 System Piping.

2-9.1 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. Hydraulic calculations shall be made in accordance with the applicable sections of NFPA 13, *Standard for the Installation of Sprinkler Systems.* (*See Appendix B.*)

2-9.1.1 Pipes shall be securely supported and, where protecting hazards in rooms where explosions are possible, pipes shall be hung from other supports than the roof so that if the roof lifts, the piping will not be broken or disarranged.

2-9.1.2 Foam distribution piping shall be arranged to drain and shall have a pitch toward drain ½ in. in 10 feet (4.2 mm/m).

2-9.1.3 Hangers. 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.

2-9.1.4 Installation. The installation standards for foam system piping shall be the applicable sections of NFPA 13, *Standard for the Installation of Sprinkler Systems*, except as herein modified. (*See Appendix B.*) Welding in accordance with ANSI B31.1, *Power Piping* (*see Appendix B*), is permissible when it can be done without introducing fire hazards. Special care shall be taken to insure that the openings are fully cut out and that no obstructions remain in the waterway. The supply piping to foam outlets which protect a hazard in a fire area shall not pass over another hazard in the same fire area.

2-10 Alarms.

2-10.1 A local alarm, actuated independently of water flow, to indicate operation of the automatic detection equipment shall be provided on each system. Central station or proprietary station water-flow alarm service is desirable but provision of this service does not waive the local-alarm requirement.

2-10.2 Outdoor water-motor or electric-alarm gongs, responsive to system water flow, may be required by the authority having jurisdiction.

2-10.3 Under conditions where central station or proprietary station water-flow alarm service is not available, it may be advisable to connect electrical alarm units to public Fire Department Headquarters or nearest Fire Department Station or other suitable place where aid may be readily secured.[1]

2-10.4 A suitable trouble alarm shall be provided for each system to indicate failure of automatic detection equipment (including electric supervisory circuits) or other such devices or equipment upon which the system operation is dependent.

2-11 Plans and Specifications.

2-11.1 The designing and installation of these systems shall be entrusted to only fully experienced and responsible persons. Before such systems are installed, complete working plans and specifications shall be submitted for approval to the authority having jurisdiction. Working plans shall be drawn to scale, show all essential details, and be so made that they can be easily reproduced to provide the necessary copies. Information required includes the design purpose of the system; discharge densities and period of discharge; hydraulic calculations; details of tests of available water supply; detailed layout of the piping and of the heat-responsive operating equipment; type of discharge devices to be installed; location and spacing of discharge devices; pipe-hanger installation details; location of draft curtains; an accurate and complete layout of the buildings or hazards to be protected; and other pertinent data to provide a clear explanation of the proposed design.

2-11.1.1 In addition to the items listed in 2-11.1, plans and specifications shall indicate the quantity and type of air foam producing material to be stored, including the quantity in reserve; and the concentration designation, such as 3 percent or 6 percent.

2-11.2 The specifications shall include the specific tests that may be required to meet the approval of the authority having jurisdiction and shall indicate how costs of preparing the area, testing, and cleanup is to be borne.

---

[1]See NFPA 71, *Central Station Signaling Systems;* NFPA 72A, *Local Protective Signaling Systems;* NFPA 72B, *Auxiliary Protective Signaling Systems;* NFPA 72C, *Remote Station Protective Signaling Systems;* and NFPA 72D, *Proprietary Protective Signaling Systems.* (*See Appendix B.*)

2-11.3 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.

2-11.3.1 Charts showing head, delivery, efficiency and brake horsepower curves of pumps shall be furnished by the contractor.

2-11.3.2 Controllers governing the starting of electric driven concentrate pumps shall be of approved types. Where control equipment listed by a nationally recognized testing laboratory for fire protection service is not available, suitable listed industrial-control equipment with adequate interrupting capacity in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, may be used. (*See Appendix B.*)

Chapter 3

Fixed Systems for Exterior Storage Tanks

*3-1 General.

3-1.1 Object. This chapter contains requirements which apply specifically to the 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 the maximum solution flow for protecting a single tank and the required supplementary hose streams.

NOTE: Tanks containing Class III liquids are not, as a rule, required to be protected by foam. Foam protection for Class III liquids may be desirable where abnormal situations exist, such as storage of high value stocks or liquids heated above their flash point.

3-1.2 Definitions.

3-1.2.1 Fixed Foam Discharge Outlet. A device permanently attached to a tank by means of which foam is introduced into the tank.

***3-1.2.2 Type I Discharge Outlet.** An approved discharge outlet which will conduct and deliver foam gently onto the liquid surface without submergence of the foam or agitation of the surface.

***3-1.2.3 Type II Discharge Outlet.** An approved discharge outlet which does not deliver foam gently onto the liquid surface but is designed to lessen submergence of the foam and agitation of the surface.

***3-1.2.4 Subsurface Foam Injection.** Discharge of foam into a storage tank from an outlet at the tank bottom or below the liquid surface.

3-1.2.5 Fixed Installations. These are complete installations piped from a central foam house to the tanks, discharging through fixed delivery outlets on the tanks. Any required pumps are permanently installed.

***3-1.2.6 Semi-fixed Installations.**

(a) The type in which tanks are equipped with fixed discharge outlets connected to piping which terminates at a safe distance from the tanks. 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-producing solutions are piped from a central foam house through the area, the solution being delivered through hose lines to portable foam towers which are erected after the fire starts (Chapter 5); or applied by hose streams (Chapter 4).

3-2 Foam Application Rates.

3-2.1 Rates. The minimum delivery rate shall be as follows:

3-2.1.1 Tanks Containing Liquid Hydrocarbons. For air foam systems, the foam solution delivery rate shall be at least 0.1 gpm/sq. ft. (4.1 $l/\text{min}\cdot m^2$) of liquid surface area of the tank to be protected.

NOTE 1: 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 2: 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 which 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.

***3-2.1.2 Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams.** Water soluble and certain flammable and combustible liquids and polar solvents which are destructive to regular foams require the use of alcohol type foams. Systems using these foams require special engineering consideration. Conditions other than routine may require that higher application rates be used. In all cases, the manufacturer of the foam concentrate and the foam-making equipment shall be consulted as to the 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.	Solution Rate $l/\text{min}\cdot m^2$
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	6.1
Butyl alcohol	0.15	6.1
Isopropyl ether	0.15	6.1

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, that is, 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 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 combustible or flammable liquids which are highly toxic, high application rates may be desirable to reduce respiratory hazard to personnel by providing for more rapid coverage of the tank contents.

***3-2.1.3 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 hose stream shall have a solution rate of at least 50 gpm (189 *l*/min) with the minimum number of hose streams shown below:

Diameter of Largest Tank	Minimum number of hose streams required
Up to 65 ft. (19.8 m)	1
Over 65 to 120 ft. (19.8 to 36.6 m)	2
Over 120 ft. (36.6 m)	3

3-3 Duration of Discharge.

3-3.1 Minimum Discharge Times. The system shall be capable of operation at the delivery rate specified in 3-2.1 for the tank to be protected, for the following minimum periods of time. If the apparatus available has a delivery rate higher than specified in 3-2.1 proportionate reduction in the time figures may be made, except that they shall not be less than 70 percent of the minimum discharge times shown.

Tanks Containing Liquid Hydrocarbons	Type of Foam Discharge Outlet Type I	Type II
Lubricating oils; dry viscous residuum (more than 50 seconds Saybolt-Fural ($1.068 \times 10^{-4} m^2/s$) at 122°F (50°C); dry fuel oils, etc. with flash point above 200°F (93.3°C)	15 min.	25 min.
Kerosene; light furnace oils, diesel fuels, etc. with flash point from 100° to 200°F (37.8 to 93.3C°)	20 min.	30 min.
Gasoline, naphtha, benzol and similar liquids with flash point below 100°F (37.8°C)	30 min.	55 min.
Crude petroleum	30 min.	55 min.

Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams

Alcohol type foams require gentle 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, unless the manufacturer of the foam concentrate has established by fire test that a shorter time can be permitted.

3-4 Foam-producing Materials.

3-4.1 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).

3-4.2 Requirements for Tanks. The quantity of foam-producing material shall be determined by multiplying the consumption rate in gpm for each tank by the appropriate time in 3-3.1. The largest resulting value shall determine the quantity required.

3-4.3 Supplementary Foam Hose Stream Requirements. 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. (10.7 m)	10 min.
Over 35 to 95 ft. (10.7 to 29.0 m)	20 min.
Over 95 ft. (29.0 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.

3-4.4 Requirements to Fill Pipe Line. A quantity of foam-producing materials sufficient to produce foam or foam solutions to fill the feed lines actually installed between the source and the most remote tank shall also be provided. Where a water supply source will continue after the foam-producing material is depleted and displace the solution or foam from the lines to the tank, no added quantity is required by this paragraph.

3-4.5 Reserve Supply of Foam-producing Materials. There shall be a readily available reserve supply of foam-producing materials as specified in 1-10.4.2.

***3-4.6 Total Supply Requirements.** Supplies to be maintained shall be the sum of the quantities specified in 3-4.2, 3-4.3, 3-4.4 and 3-4.5.

3-5 Foam Discharge Outlets.

3-5.1 Surface Application.

***3-5.1.1 Vertical Fixed Roof Atmospheric Storage Tanks.** 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 discharge 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	Metres	Minimum Number Discharge Outlets
Up to 80	24.4	1
Over 80 to 120	24.4 to 36.6	2
Over 120 to 140	36.6 to 42.7	3
Over 140 to 160	42.7 to 48.8	4
Over 160 to 180	48.8 to 54.9	5
Over 180 to 200	54.9 to 61.0	6

NOTE: It is suggested that for tanks above 200 feet (61 m) in diameter, at least one additional discharge outlet be added for each additional 5000 sq. ft. (465 m^2) of liquid surfaces. Since there has been no experience with foam application to fires in fixed roof tanks over 140 feet (42.7 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 feet (30.5 m) of burning liquid surface. On large tanks, 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.

*3-5.1.2 **Open Top Floating Roof Storage Tanks.** Fixed outlets are generally not required on open top floating roof tanks. These tanks have an excellent fire record. Their design has been for the purpose of fire prevention as well as for conservation of product. It is usually possible to utilize trained personnel to extinguish fires in the annular ring using portable equipment. 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 will be found in A-3-5.1.2.

*3-5.1.3 **Covered Floating Roof Tanks.** Fixed outlets are not generally required on covered floating roof tanks. The possibility of fire is greatly reduced in comparison with other types because of the Faraday Cage type construction of 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. (*See Appendix B.*)

NOTE: A "Faraday Cage" is a grounded metallic screen completely surrounding a space or piece of equipment in order to shield it from external electrostatic influence.

*3-5.1.4 **Diked Areas.** Fixed foam systems are not generally required for tank diked areas. Portable foam monitors or foam streams or both generally provide an acceptable method of protection. See 4-1.2 for the recommended method of fighting diked area fires. Where fixed system protection is desirable for diked areas, see A-3-5.1.4 for suggested design criteria.

3-5.1.5 Supplementary Protection. It is desirable that at least one portable tower or portable monitor be provided as supplementary protection in the event that a fixed discharge outlet is damaged by an explosion within the tank (*see Chapters 4 and 5*).

3-5.2 Subsurface Application to Fixed Roof Storage Tanks Containing Liquid Hydrocarbons.

***3-5.2.1 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-3-5.2.1.

3-5.2.2 Limitations. Subsurface injection systems are not suitable for protection of products such as alcohols, esters, ketones, aldehydes, anhydrides, etc. Liquid hydrocarbons that contain such products which are foam destructive may require higher application rates. The manufacturer of the foam system shall be consulted for recommendations. Subsurface or semi-subsurface injection systems are not recommended for floating roof tanks because of the possibility of improper distribution of foam to the fuel surface.

***3-5.2.3 Foam-producing Materials and Equipment.** Foam-producing materials and equipment for subsurface injection shall be listed for this purpose. Fluoroprotein foam concentrates will provide satisfactory subsurface injection performance.

3-5.2.4 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 feet per second (3.05 m/s) for Class IB liquids or 20 feet per second (6.1 m/s) for other type liquids unless actual tests prove higher velocities are satisfactory (*see A-3-6.2*).

Where two or more outlets are required, they shall be located so that the foam travel on the surface does not exceed 100 feet (30.5 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. Shell connections may be made in manway covers rather than installing additional tank nozzles.

3-5.2.5 Tanks shall be provided with discharge outlets as set forth on the following page:

Tank Diameter Feet	Tank Diameter Metres	Minimum Number of Discharge Outlets Required: Class IB Liquids	Minimum Number of Discharge Outlets Required: Classes IC, II & III Liquids
Up to 80	24.4	1	1
Over 80 to 120	24.4 to 36.6	2	1
Over 120 to 140	36.6 to 42.7	3	2
Over 140 to 160	42.7 to 48.8	4	2
Over 160 to 180	48.8 to 54.9	5	2
Over 180 to 200	54.9 to 61.0	6	3
Over 200 ft. (61.0 m) add one inlet for each additional		5000 sq. ft. (465 m²)	7500 sq ft. (697 m²)

NOTE 1: Class IA liquids require special consideration.

NOTE 2: The above table is based on extrapolation of fire test data on 25, 93 and 115 foot (7.6, 28.4 and 35.1 m) diameter tanks containing gasoline, crude and hexane, respectively.

NOTE 3: The most viscous fuel which has been extinguished by subsurface injection when stored at ambient temperatures (60°F [15.6°C]) had a viscosity of 25 S.S.F. at 122°F (50°C) and a pour point of 15°F (−9.4°C). This is similar to heavy fuel oil. In addition to the control provided by the smothering effect of the foam and the cooling effect of the water in the foam which reaches the surface, fire control and extinguishment may be further enhanced by the rolling of cool product to the surface. No known tests have been conducted on product having a higher viscosity than this fuel oil.

3-5.2.6 Foam Discharge Outlet Elevation. Foam discharge outlets shall be located so 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, 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.

3-5.3 Horizontal Atmospheric and Pressure Tanks. Fixed outlets are not recommended to discharge into horizontal or pressure tanks.

3-6 Foam System Piping.

3-6.1 General Requirements.

3-6.1.1 All piping inside of dikes and within 50 feet (15 m) of tanks not diked shall either be buried under at least one foot (0.3 m) of earth or if above ground shall be properly supported and protected against mechanical injury.

3-6.1.2 Piping which is normally filled with liquids, such as the suction pipes, shall be protected from freezing when necessary.

3-6.1.3 Piping from the dike or within 50 feet (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:

(a) 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 a system of approved standard weight steel, ductile or malleable iron fittings.

(b) When piping is supported above ground, it shall have upward and lateral support as needed, but shall not be held down a distance of 50 feet (15 m) from the tank shell to provide flexibility in an upward direction so that a swing joint is not needed. If threaded connections occur within this distance they shall be back welded for strength.

(c) When tank risers are four-inch 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 above ground flexibility as described above.

3-6.1.4 One flanged or union joint shall be provided in each riser within five feet of the ground 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.

3-6.1.5 In systems with semi-fixed equipment on fixed roof tanks, the foam or solution laterals to each foam chamber shall terminate in connections which are at a safe distance from the tanks; outside of dikes and at least 50 feet (15 m) from tanks of 50 feet (15 m) in 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.

***3-6.2 Back Pressure Requirements.** 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 nationally recognized testing laboratories.

3-6.3 Valves in Systems. All valves, except hydrant valves, shall be the O.S. and Y. or post indicator type. The laterals to each foam chamber on fixed roof tanks shall be separately valved outside the dike in fixed installations. Control valves to divert the foam or solutions to the proper tank may be in the central foam house or may be at points where laterals to the protected tanks branch from main feed line. Control valves shall be located outside dikes and not less than the following distances from the shell of the tank which they serve: 50 feet (15 m) for tanks less than 50 feet (15 m) in diameter; one diameter for tanks 50 feet (15 m) in diameter or larger, except that control 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 air 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 air foam 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 foam-generator to be connected at time of use. When product lines are used for foam, product line valving shall be arranged to ensure foam enters only the tank to be protected.

3-6.4 Foam Hose Outlets. Centralized fixed piping systems shall be provided with hose outlets for foam hose streams for supplementary use on spill fires, supplying portable towers, etc. In lieu of foam (or solution) outlets, water hydrants and portable proportioners or other devices acceptable to the authority having jurisdiction may be provided. The minimum number of foam outlets or water hydrants shall be located at a distance of 50 to 250 feet (15 to 76 m) from the shells of tanks protected, as specified in Table 3-6.4.

Table 3-6.4

Tank Diameter Feet	Tank Diameter Metres	Minimum Number of Outlets Required
Up to 65	19.8	1
65 and over	19.8 and over	2

Chapter 4 Monitor and Hose Nozzles for Exterior Protection

4-1 General.

***4-1.1 Object.** This chapter relates to systems in which the foam is applied through fixed or portable monitor or hose nozzles. They are recommended as auxiliary protection in conjunction with fixed piping systems or portable towers as specified in Chapters 3 and 5. They are suitable when used alone for extinguishment of spill fires, diked area fires, and fires in vertical fixed roof atmospheric storage tanks. Portable hose nozzles are suitable for extinguishments of rim fires in open top floating roof tanks.

NOTE 1: Fires in tanks up to 130 feet (39.7 m) in diameter have been extinguished when the entire liquid surface was involved by use of large capacity foam monitors. Depending on the fixed roof tank outage and fire intensity, the up-draft 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. Due to their limitations, monitors should not be depended upon as a primary means of extinguishment for fixed roof tanks over 60 feet (18.3 m) in diameter. 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. Fixed foam monitors may be installed for protection of drum storage areas or diked areas. Use of portable towers may present a safety hazard to fire fighters inside the diked area if used to apply foam to tanks containing hot oils, burning asphalts, or other liquids which are above the boiling point of water.

NOTE 2: Foam hose streams are suitable as a primary means of extinguishment of fires in tanks not over 30 feet (9.15 m) in diameter nor over 20 feet (6.1 m) high. Foam hose streams may be used for open top floating roof rim fires extinguishment when applied from the tank wind girder or roof.

4-1.2 Diked 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.

***4-1.3 Definitions.**

4-1.3.1 Foam Hose Stream. A foam stream from a hose nozzle which may be held and directed by hand. The nozzle reaction usually limits the solution flow to about 300 gpm (1136 *l*/min).

4-1.3.2 Foam Monitor Stream. A large capacity foam stream from a nozzle which is supported in position and which may be directed by one man. A solution flow of 300 gpm (1136 *l*/min) or higher can be used.

***4-1.3.3 Fixed Monitor (Cannon).** A device which delivers foam monitor stream and is mounted on a stationary support at grade or elevated. The monitor may be fed solution by permanent piping or hose.

***4-1.3.4 Portable Monitor (Cannon).** A device which delivers a foam monitor stream and is on a movable support or wheels so it may be transported to the fire scene.

4-2 Foam Application Rates.

4-2.1 Rates. The minimum delivery rate for primary protection based on the assumption that all the foam reaches the area being protected shall be as follows:

In determining total solution flow requirements, consideration shall be given to potential foam losses from wind and other factors as noted in 4-1.1, Note 1.

4-2.1.1 Tanks Containing Liquid Hydrocarbons. The foam solution delivery rate shall be at least 0.16 gpm/sq. ft. (6.5 $l/\text{min}\cdot\text{m}^2$) of liquid surface area of the tank to be protected.

NOTE 1: 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 per square foot (8.1 $l/\text{min}\cdot\text{m}^2$) or more.

NOTE 2: 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 which 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.

4-2.1.2 Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams. Water soluble and certain flammable and combustible liquids and polar solvents which are destructive to regular foams require the use of alcohol type 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 inch (25 mm). For liquids in greater depth, monitor and foam hose streams shall be limited for use with special alcohol type foams listed for Type II discharge. Systems using these foams require special engineering consideration. 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:

	Solution Rate	
Type of Liquids	**gpm/sq. ft.**	**l/min·m^2**
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.

Solution transit time, that is, 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 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 pressures, 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 flammable or combustible liquids which are highly toxic, higher application rates may be desirable to reduce respiratory hazard to personnel by providing for more rapid coverage.

4-2.1.3 Supplementary Hose Stream Requirements. Additional foam hose streams and required equipment shall be provided as supplemental protection for ground fires at least as specified in 3-2.1.3.

4-3 Duration of Discharge.

4-3.1 Minimum Discharge Times. The equipment shall be capable of operation to provide primary protection at the delivery rates specified in 4-2.1 for the following minimum periods of time.

Tanks Containing Liquid Hydrocarbons

Lubricating Oils; dry viscous residuum (more than 50 seconds Saybolt-Furol [1.068 x $10^{-4}m^2/s$] at 122°F [50°C]); dry fuel oils, etc. with flash point above 200°F (93.3°C)	35 min.
Kerosene; light furnace oils, diesel fuels, etc. with flash point 100°F to 200°F (37.8 to 93.3°C)	50 min.
Gasoline; naphtha, benzol, and similar liquids with flash point below 100°F (37.8°C).	65 min.
Crude petroleum	65 min.

Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams

Alcohol type foams require special application procedures as discussed in 4-2.1.2. 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.

4-3.2 Extinguishment of Spill Fires. Where the primary purpose of the protection is for extinguishment of spill fires, the minimum discharge time shall be 10 minutes for fixed equipment. For portable equipment, the minimum discharge time shall be 15 minutes. For protection of diked areas designed to contain the contents of a storage tank, see 4-1.2.

4-4 Foam-producing Materials.

4-4.1 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).

4-4.2 Requirements for Tanks. The quantity of foam-producing material shall be determined by multiplying the consumption rate in gallons per minute for each tank by the appropriate time in 4-3.1. The largest resulting value shall determine the quantity required.

4-4.3 Supplementary Foam Hose Stream Requirements. Additional foam-producing materials shall be provided to permit operation of hose stream equipment simultaneously with tank foam installations as specified in 3-4.3.

4-4.4 Requirements to Fill Pipe Lines. These shall be the same as specified in 3-4.4 when piping is part of the design.

4-4.5 Reserve Supply of Foam-producing Materials. There shall be a reserve supply of foam-producing materials the same as specified in 1-10.4.2.

4-4.6 Total Supply Requirements. Supplies to be maintained shall be the sum of the quantities specified in 4-4.2, 4-4.3, 4-4.4 and 4-4.5.

4-4.7 Requirements for Spill Fires. Sufficient foam-producing materials shall be available for extinguishment of spill fires as defined in 4-3.1 and, in addition, as specified in 4-4.4 and 4-4.5.

4-5 Hose Requirements.

4-5.1 Unlined Fabric Hose. Unlined fabric hose shall not be used with foam equipment.

Chapter 5 Portable Tower Systems for Exterior Storage Tanks

5-1 General.

5-1.1 Object. This chapter relates to those systems in which the foam is applied through approved portable towers which are placed in operating position after the fire starts.

NOTE 1: Generally, portable towers are to be regarded as limited in use. Portable tower systems require accessibility to tankage, and an adequate number of men to place and maintain the apparatus in operation; and in some cases, special truck units for the ready transportation of the equipment to the location of the fire. The adequacy of a portable tower system, subject to the approval of the authority having jurisdiction, should be based upon the number and availability of the men and equipment to extinguish a possible fire. On tanks over 200 feet (61 m) in diameter, the use of a portable foam tower may not be practical, due to the amount of equipment and number of men needed to meet requirements.

NOTE 2: Tanks containing 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 point. Use of portable towers may present a safety hazard to fire fighters inside the diked area if used to apply foam to tanks containing hot oils, burning asphalts, or other liquids which are above the boiling point of water.

***5-1.2 Definitions.**

5-1.2.1 Portable Foam Tower. A device which 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.

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 Chapter 4.

5-1.2.2 Portable Installations. The type in which the foam apparatus, foam-producing materials, hose, etc., are transported to the scene after the fire starts, the foam being delivered to the tank by portable towers.

5-2 Foam Application Rates.

5-2.1 Rates. The minimum delivery rate shall be as specified in 3-2.1.

5-2.2 Supplementary Foam Hose Stream and Hose Outlet Requirements. The minimum requirements for hose streams and hydrants shall be as specified in 3-2.1.3.

5-3 Duration of Discharge.

5-3.1 Minimum Discharge Time. The system shall be capable of operation at the delivery rate specified in 5-2.1 for the following minimum periods of time. If the apparatus available has a delivery rate higher than that specified in 5-2.1, proportionate reduction in the time figures may be made, except that they shall not be less than 70 percent of the minimum discharge times shown.

Tanks Containing Liquid Hydrocarbons	Type of Portable Foam Tower Type I	Type II
Lubricating oils, dry viscous residuum (more than 50 seconds Saybolt-Furol [1.068 x 10^{-4} m^2/s] at 122°F [50°C]), dry fuel oils, etc., with flash point above 200°F (93.3°C)	25 min.	35 min.
Kerosene, light furnace oils, diesel fuels, etc., with flash point from 100°F to 200°F ((37.8 to 93.3°C)	30 min.	50 min.
Gasoline, naphtha, benzol and similar liquids with flash point below 100°F (37.8°C)	55 min.	65 min.
Crude petroleum	55 min.	65 min.

Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams

Alcohol type foams require gentle application by Type I outlets unless listed as suitable for application through Type II devices. The operation time shall be 55 minutes at the specified application rate, unless the manufacturer of the foam concentrate has established by fire test that a shorter time may be permitted.

5-4 Foam-producing Materials.

5-4.1 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).

5-4.2 Requirements for Tanks. The quantity of foam-producing material shall be determined by multiplying the consumption rate in gallons per minute for each tank by the appropriate time in 5-3.1. The largest resulting value shall determine the quantity required.

5-4.3 Supplementary Hose Stream Requirements. Additional foam-producing materials shall be provided to permit operation of the hose stream equipment simultaneously with tank foam installations as specified in 3-4.3.

5-4.4 Requirements to Fill Pipe Lines. These shall be the same as specified in 3-4.4.

5-4.5 Reserve Supply of Foam-producing Materials. There shall be a reserve supply of foam-producing materials the same as specified in 1-9.4.2.

5-4.6 Total Supply Requirements. Supplies to be maintained shall be the sum of the quantities specified in 5-4.2, 5-4.3, 5-4.4 and 5-4.5.

5-5 Foam Towers.

5-5.1 Number Required. Towers shall be available in the proper number and size as to deliver foam on the burning liquid surface at a rate to meet the requirements of 5-2.1 and as set forth in Table 5-5.1.

Table 5-5.1

Tank Diameter (or equivalent area) Feet	Metres	Minimum Number Foam Towers
Up to 80	24.4	1
Over 80 to 120	24.4 to 36.6	2
Over 120 to 140	36.6 to 42.7	3
Over 140 to 160	42.7 to 48.8	4
Over 160 to 180	48.8 to 54.9	5
Over 180 to 200	54.9 to 61.0	6

NOTE 1: When two or more towers are required, they should be sized to deliver foam at approximately the same rate.

NOTE 2: Since there has been no experience with foam application to fires in fixed roof tanks over 140 feet (42.7 m) in diameter, requirements for foam protection on tanks above this size are based on extrapolation of data from successful extinguishments in smaller tanks.

5-6 Centralized Fixed Piping Systems.

5-6.1 Foam Tower Hose Outlets. Hose outlets used for foam towers shall be as specified in 3-6.4.

Chapter 6 Spray Foam Systems for Exterior Protection

6-1 General.

***6-1.1 Object.** This chapter relates to systems discharging air foam in a spray pattern that can be effectively used to extinguish spill fires under or around process structures and equipment, horizontal tanks and small vertical tanks. These systems relate to spray discharge of air foam only. Some foam spray systems and devices are not designed to produce effective water patterns for cooling purposes. For system design criteria for discharge of both water and foam, refer to NFPA 16, *Standard for Installation of Foam-Water Sprinkler and Foam-Water Spray Systems.* (*See Appendix B.*)

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.

Foam is not considered an effective agent for extinguishment of three-dimensional running flammable liquid fires. However, in the event of such a fire, the foam can effectively cover and control the pool fire beneath the running fire, thus facilitating approach and extinguishment by other means.

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

6-2 Foam Application Rate.

6-2.1 Rate. The minimum rate of foam solution application shall be 0.16 gpm/sq. ft. (6.5 $l/\text{min}\cdot m^2$) for the maximum potential fire area.

6-3 Duration of Discharge.

6-3.1 Minimum Discharge Time. There shall be a quantity of foam-producing materials sufficient to supply the system at the design rate for a period of 10 minutes. If the system discharges at a rate above the minimum specified in 6-2.1, then the operating time may be reduced proportionately, but shall not be less than 7 minutes.

6-4 Foam-producing Materials.

6-4.1 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).

6-4.2 Reserve Supply. There shall be a reserve supply of foam-producing materials in accordance with 1-10.4.2.

6-4.3 Total Supply Requirements. Supplies to be maintained shall be the sum of the quantities specified in 6-3.1 and 6-4.2.

6-5 Foam Discharge Outlets.

6-5.1 Number and Location. There shall be a minimum of 1 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 located so 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.

6-6 Operation.

6-6.1 Automatic Operation. This may be accomplished by use of listed fire detectors installed in accordance with their accepted spacing rule for outdoor applications, and connected to a deluge valve and other equipment to make a complete system. The requirements of 2-4.2 and 2-10 shall be complied with where applicable and an auxiliary manual tripping means shall be provided.

6-6.2 Manual Operation. Controls shall be located in an accessible place, sufficiently removed from the hazard so that they may be safely operated in an emergency. The location and purpose of the control shall be plainly indicated.

6-7 Foam System Piping.

6-7.1 General Requirements.

(a) Piping which will normally be filled with liquid shall be protected against freezing when necessary.

(b) The requirements of 2-9 shall be complied with where applicable.

6-7.2 Applicable parts of Chapter 3 of NFPA 13, *Standard for the Installation of Sprinkler Systems* (*see Appendix B*), shall be consulted for requirements applicable to piping, valves, pipe fittings, and hangers, including corrosion-protection coatings (galvanizing or other means). In these open-head systems, galvanized pipe and fittings shall be used for normal occupancies. Corrosive atmospheres may require other coatings.

Since the systems herein covered are required to be hydraulically designed, the pipe-size tables of NFPA 13, *Standard for Installation of Sprinkler Systems* (*see Appendix B*), are not applicable.

6-7.3 Piping carrying foam concentrate shall be black steel or cast iron.

Chapter 7 Tests for the Physical Properties of Foam

***7-1 General.** This chapter relates to the laboratory tests of foam concentrate or foam-producing devices when it is desired to correlate physical characteristics with fire extinguishing properties.

***7-1.1 Scope.** Section A-7-1.1 contains detailed laboratory procedures for the sampling and analysis of fire fighting foam.

Appendix A

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

A-1-5.1.1 Air Foam Hose Nozzle with Built-in Inductor. Figure A-1-5.1.1 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 six feet (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.

Figure A-1-5.1.1 Air foam nozzle with built-in inductor.

A-1-5.1.2(a) In-line Inductor. This inductor 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 inductor must be designed for the particular foam maker or playpipe with which it is to be used. The device is very sensitive to down-stream 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 inductor 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 inductor.

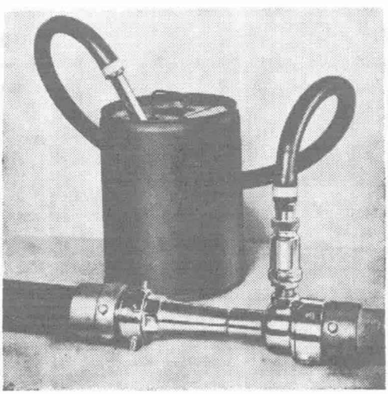
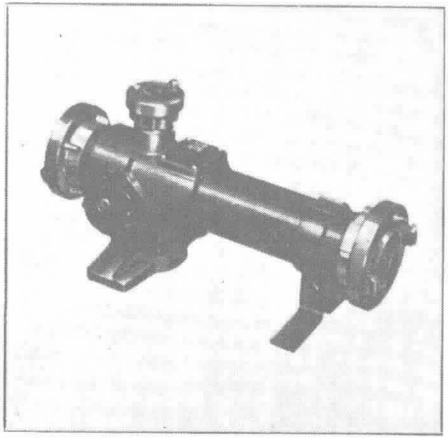


Figure A-1-5.1.2(a)(1) In-line inductor.



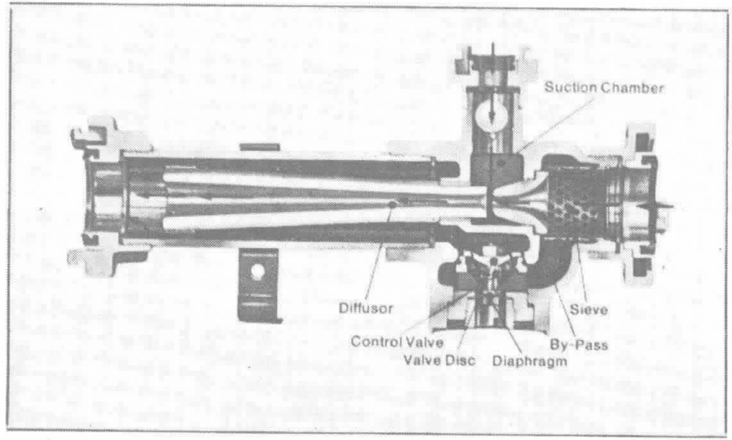


Figure A-1-5.1.2(a)(2) In-line inductor.

A-1-5.1.2(b) Primary–Secondary Induction Method. This method of introducing air foam concentrate into the water stream en route to a fixed foam maker is illustrated in Figure A-1-5.1.2(b).

The unit consists of two inductors designated as the primary inductor and the secondary inductor. The primary inductor 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 inductor and draws the concentrate from a container by means of a pick-up tube.

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

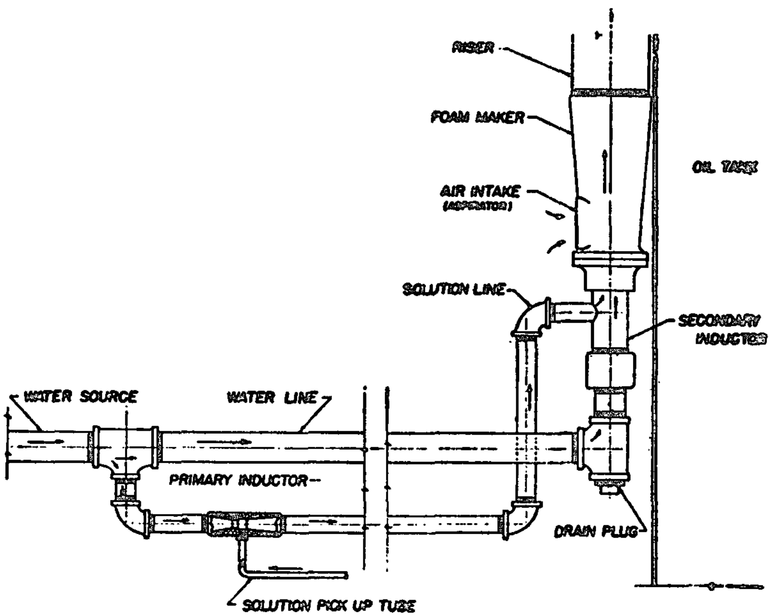


Figure A-1-5.1.2(b) Air foam auto-induction system. Solution pick-up tube picks up concentrate from its container.

Limitations.

1. The primary inductor may be installed as much as 500 ft. (153 m) from the secondary inductor. 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 inductor.

A-1-5.1.3 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 gauge pressure or on the vacuum side. A small positive pressure of 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.

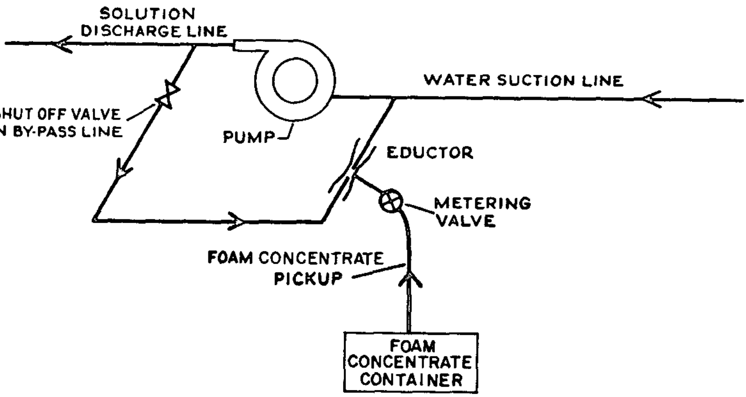


Figure A-1-5.1.3 Around-the-pump proportioner.

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-1-5.1.4 Balanced Pressure 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 inductor may be inserted in the line at any point between the water source and foam maker or playpipe.

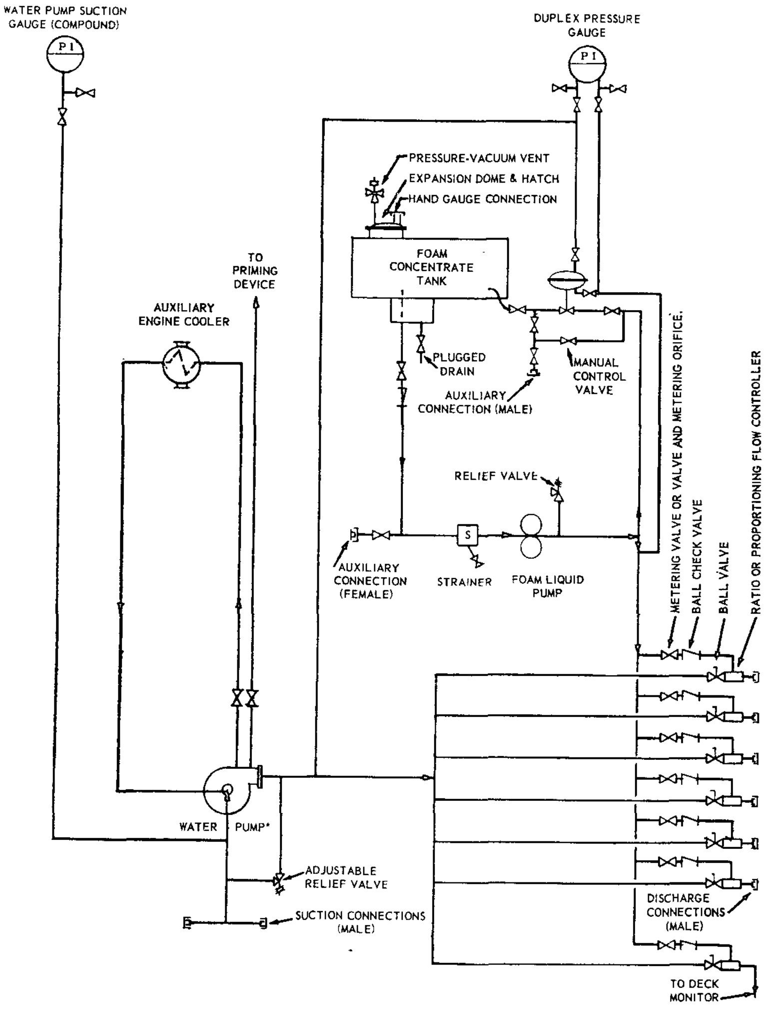


Figure A-1-5.1.4 Balanced pressure proportioning.

To operate, the main water valve is opened and a reading of the pressure indicated on the duplex gauge is taken. The bypass valve in the line between the suction and discharge of the foam concentrate pump should be opened fully and the pump started. By slowly closing the bypass valve to increase the discharge pressure of the foam concentrate, the second pointer on the duplex gauge is brought to coincide with the indicated water pressure. When both gauge hands are set at the same point, the proper amount of foam concentrate is being injected into the water stream.

Limitations.

1. The capacity of the proportioner may be varied from approximately 50 percent 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 inductor within the capacity limits given above.

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

A-1-5.1.5 Pressure Proportioning Tank Method. The arrangement of these devices may take a variety of forms. A single tank or battery of tanks manifolded together may be used. There are also single tanks divided into two separate compartments by a bulkhead and dual tank arrangements.

Where single tanks or a battery of manifolded tanks are used, it is necessary to interrupt foam production while recharging. With the compartmented tank or dual tank arrangement, continuous operation can be secured. The smaller devices are portable for use with hose streams.

The device illustrated in Figure A-1-5.1.5 shows a pressure proportioning tank with a single operating head.

Limitations.

1. The capacity of these proportioners may be varied from approximately 50 percent 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 within the capacity limits given above.

3. The length of time these devices will operate before recharging is necessary is given on the nameplate as a function of the water flowing through the eductor. This time may vary from 2 or 3 minutes for a small unit, up to 15 minutes or longer for the larger units.

4. After each use, these units must be completely emptied and recharged.

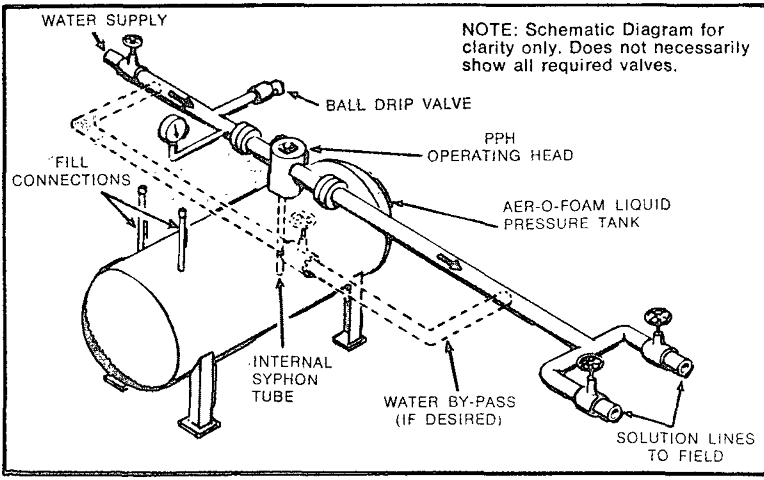


Figure A-1-5.1.5 Typical arrangement of pressure proportioner with single operating head.

A-1-5.1.6 Coupled Water Motor Pump. This device consists of two positive displacement rotary pumps mounted on a common shaft. Water delivered to the larger pump causes it to drive the smaller pump which is used to draft concentrate from a container and deliver it to the water discharge line from the larger pump. By proportioning the sizes of the two pumps, the correct volume of concentrate is delivered to the water stream.

Limitations. The pressure drop across this proportioner is 25 percent at 100 psi (690 kPa) at maximum flow. The volume of water flow governs the volume of stabilizer delivered into the water stream. It is manufactured in only two sizes. The smaller will proportion within acceptable limits between 60 and 180 gpm (227 to 681 *l*/min). The larger will proportion between 200 and 1000 gpm (757 to 3785 *l*/min) with concentrate concentrations between 6½ and 5½ percent. It has no limitations in respect to pressure.

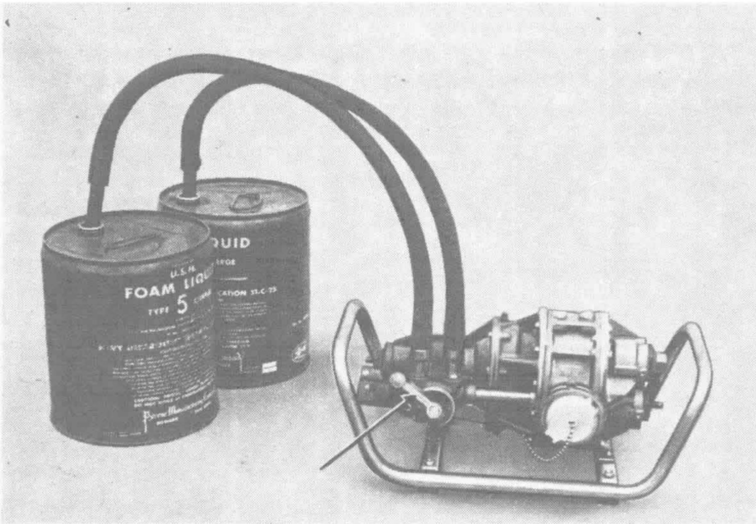


Figure A-1-5.1.6 Coupled water motor pump proportioner.

A-1-5.2.1(a) Fixed Foam Makers for Air Foam. In installations such as dip tanks, quench tanks, etc., as illustrated, the foam maker may be installed in connection with a vessel of concentrate from which the concentrate is drawn by the flowing water passing through the foam maker. Such devices may be automatically or manually operated by controlling a single valve.

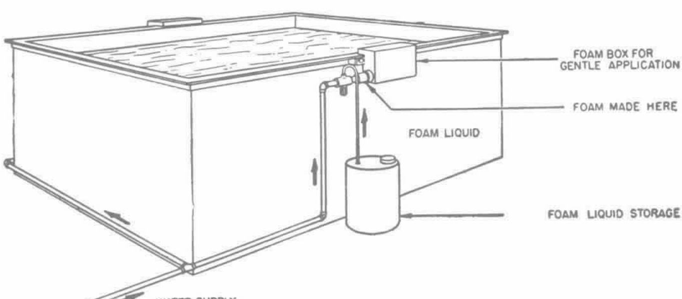


Figure A-1-5.2.1(a) Schematic diagram showing protection of dip tanks with air foam system. Foam liquid concentrate storage in vessel beside dip tank.

A-1-5.2.1(b) Air Foam Hose Stream Nozzles.

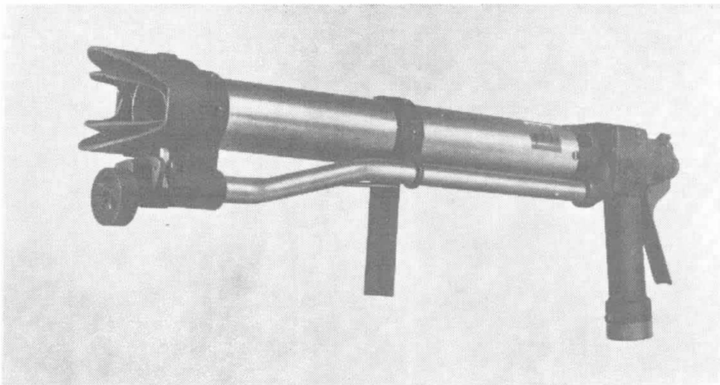


Figure A-1-5.2.1(b) Handline foam nozzle.

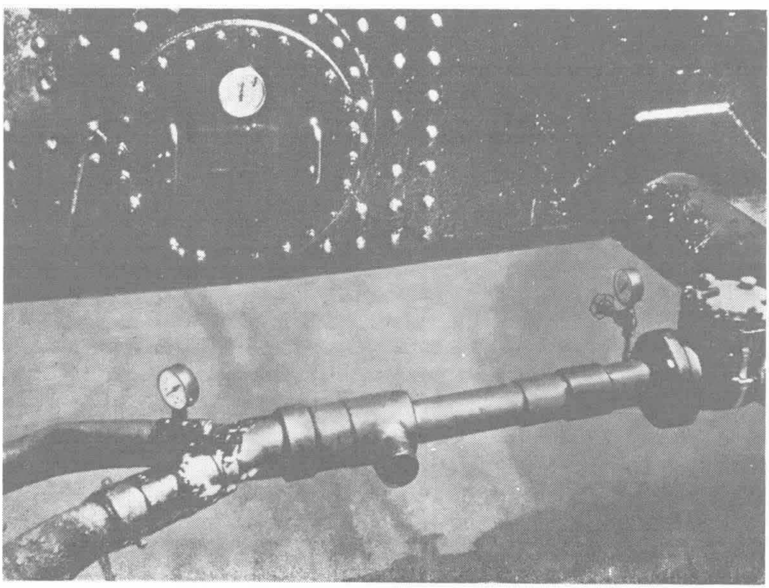


Figure A-1-5.2.2 High back pressure foam maker.

A-1-6.1 Foam Powder.

(a) Dual foam powder produces 8 to 12 gals. of foam per pound (67 to 100 *l* per kg) of powder consumed, depending on the apparatus used and the conditions of use. Modern dual generators produce from 11 to 16.5 gals. of foam per gallon (11 to 16.5 *l* per litre) of water consumed.

(b) Single foam powder produces 7 to 11.5 gals. of foam per pound (58 to 96 *l* per kg) of powder consumed, depending on the apparatus used and the conditions of use. Modern single powder generators produce from 10 to 19.5 gals. of foam per gallon (10 to 19.5 *l* per litre) of water consumed.

(c) The special foam powder produces 5 to 7.5 gals. of foam per pound (42 to 63 *l* per kg) of powder consumed depending on the apparatus used and the conditions of use. Modern single powder generators using this material produce from 6.5 to 11.5 gals. of foam per gallon (6 to 11.5 *l* per litre) of water consumed.

This special foam powder is effective on fires involving water soluble solvents, among which are the following:

Alcohols

Methyl alcohol
Ethyl alcohol
Propyl alcohols
*Butyl alcohols
*Diacetone alcohol

Esters

Methyl acetate
Ethyl acetate

Ethers

Ethyl ether
Isopropyl ether
Amyl ether
Dioxane
Ethyl cellosolve
Butyl cellosolve
*Carbitol
*Butyl carbitol

Ketones

Acetone
Methyl ethyl ketone

*These represent borderline cases in which the material destroys ordinary foam to some extent. A higher than usual rate of regular foam application is necessary to achieve effectiveness ordinarily encountered on petroleum products.

Ordinary foam powder is suitable for use on fires involving iso-octyl alcohol.

Where materials other than those listed require protection, the manufacturer of foam-producing materials should be consulted as to type of foam and rate of application necessary to secure extinguishment.

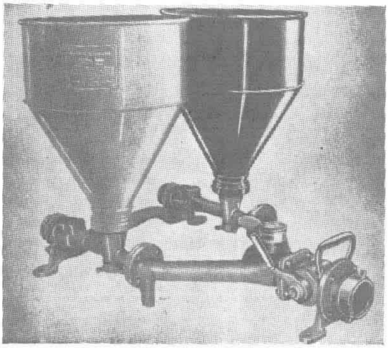


Figure A-1-6.1(a) Dual hopper chemical foam generator of the two powder type.

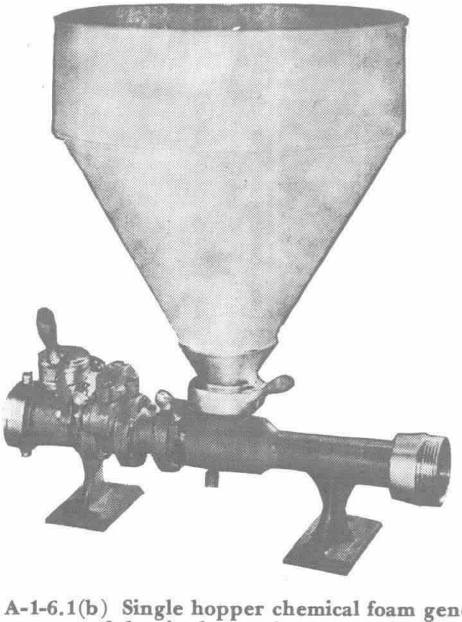


Figure A-1-6.1(b) Single hopper chemical foam generator of the single powder type.

NOTE 1: The foam produced by powders referred to in (a) and (b) disintegrates rapidly when applied to most water soluble solvents such as certain alcohols, ketones, ethers, etc., and is not considered effective in the extinguishment of fires involving these liquids.

NOTE 2: Foam expansion depends on a number of factors, among which are:

a — Type of foam powder.
b — Water temperatures.
c — Atmospheric temperatures.

The values given above are for water temperatures between 50° and 70°F (10° and 21°C). Low water temperatures retard the chemical reaction. Warm water may result in higher expansion at the expense of the quality of the foam.

A-1-6.3 Storage of Chemical Foam Materials. Where water solutions of the acidic and alkaline salts necessary for the production of chemical foams are stored separately in tanks (wet storage), provision is made for factors of corrosion, solution deterioration, contamination, and system restoration after use. Materials of fabrication in contact with the solutions are carefully chosen. Facilities are provided for periodically testing the solutions for deterioration under long storage (especially the bicarbonate content of the alkaline solution). Prevention of contamination of the tank contents by foreign substances and methods for speedily recharging the tanks with solutions after the system has been used are also taken into consideration. Where dry foam powders are stored in the containers in which they are transported or where bulk storage of the powders is relied upon, the containers must be kept tightly closed in a cool dry storage area. Inspection of powders is periodically conducted. Water and moisture exposure of chemical foam powders and temperature exposure fluctuation of all components of chemical foam systems above 120°F (48.9°C) or below 50°F (10°C) is carefully avoided.

A-1-7.2 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, 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-1-7.2(b) Other auxiliary agents compatible with foams should be provided in conjunction with foams for fighting fires of this nature.

A-1-7.2(f) Precautions should be taken to ensure that such agents are fully compatible with the types of foams being used.

A-1-9.5 Strainers. Where the water is clear, a simple strainer should be provided. Where the water is moderately contaminated, self-cleaning strainers accessible for cleaning during the emergency should be used. Dual type strainers, or the equivalent, may be necessary if water supplies are badly contaminated. Strainers may be installed in the water supply line or as part of the foam apparatus. Strainers may also be required near foam makers served by long pipe lines where scale may exist.

A-1-11 Tests.

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

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

2. The laboratory 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 systems performance.

1. Static water pressure.

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

3. Rate of consumption of foam liquid concentrate.

The concentration of foam liquid in 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 authority having jurisdiction.

A-2-5.4 There should be a minimum of one (1) discharge outlet per 100 square feet (9.3 m^2) of protected area unless listing of discharge devices indicates a larger spacing is permitted. These outlets should be located so as to provide good distribution throughout the protected area. An advantage is gained by locating the outlets so that foam discharge envelops the equipment within the protected area. These outlets are located in plan and elevation to provide the most effective protection of the hazard.

A-2-5.7 Consideration should be given to provisions of remotely located post-indicator or other shut-off valves to permit system water-supply control under abnormal conditions.

A-3-1 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 large oil 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.

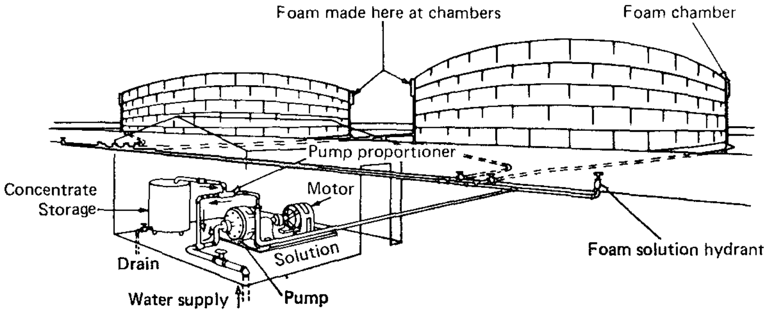


Figure A-3-1 Schematic arrangement of air foam protection for storage tanks.

A-3-1.2.2 Type I Discharge Outlets. Among the approved Type I discharge outlets are:

(a) Porous asbestos tube [*see Figure A-3-1.2.2(a)*]

(b) Foam trough along the inside of tank wall [*see Figure A-3-1.2.2(b)*]

(c) Foam chute or ladder [*see Figure A-3-1.2.2(c)*].

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 Asbestos Tube. The coarsely woven asbestos tube is rolled up in the foam chamber, one end being securely fastened to the foam supply line, the free end being stitched so 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 flows forth through the interstices of the fabric directly onto the liquid surface.

Foam Trough. The trough shown schematically in Figure A-3-1.2.2(b) consists of sections of steel sheet formed into a chute which 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.

Foam Chute. The device illustrated in Figure A-3-1.2.2(c) consists of a foam mixing chamber (external to the tank) and an internal delivery conduit or chute. Staggered openings are provided at intervals in the conduit. The foam delivered piles up in the chute and emerges through the first opening immediately above the liquid surface. The discharge of foam through the higher openings is prevented by the use of baffles which shield the openings. The maximum distance that the foam must drop onto the liquid surface is regulated by the spacing of the overflow outlets.

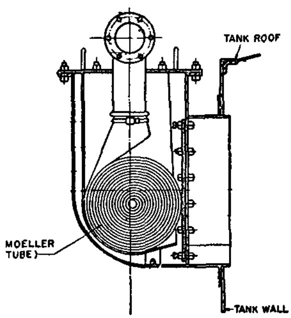


Figure A-3-1.2.2(a) Cross-section Moeller tube chamber.
Tube is designed to unroll and fall to oil level.
Foam flows through interstices in tube.

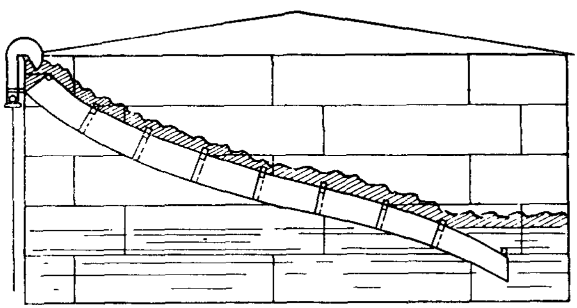


Figure A-3-1.2.2(b) Foam trough.

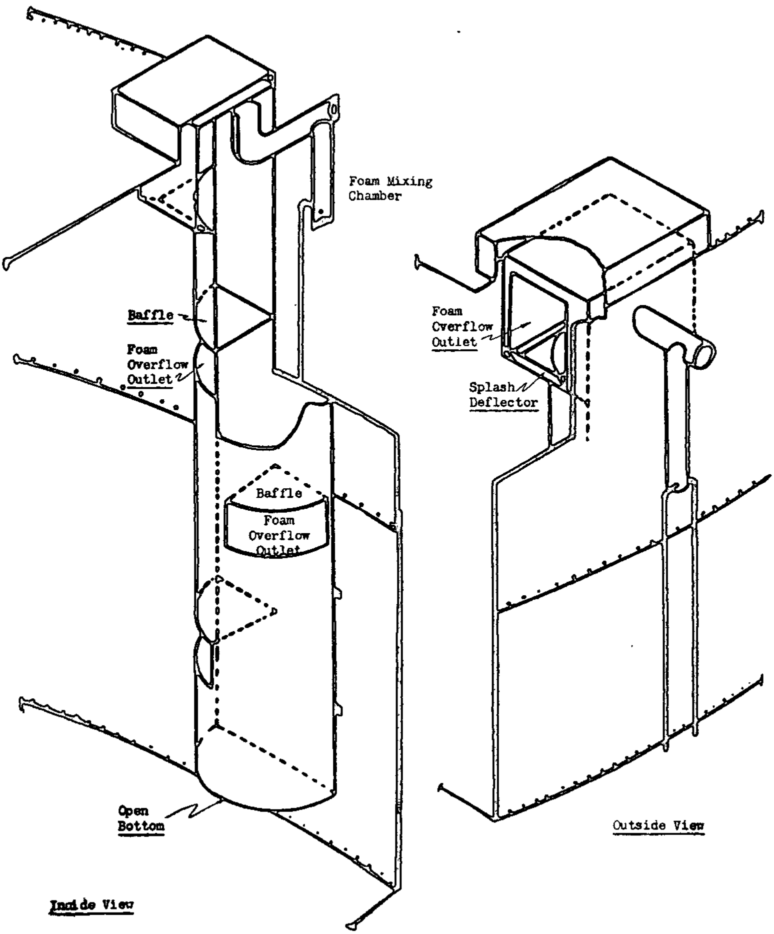


Figure A-3-1.2.2(c) Foam chute.

A-3-1.2.3 Type II Discharge Outlets. See Figures A-3-1.2.3 and A-3-1.2.4.

Where Type II outlets are used with alcohol type hazards, the manufacturer should be consulted for adequacy of protection.

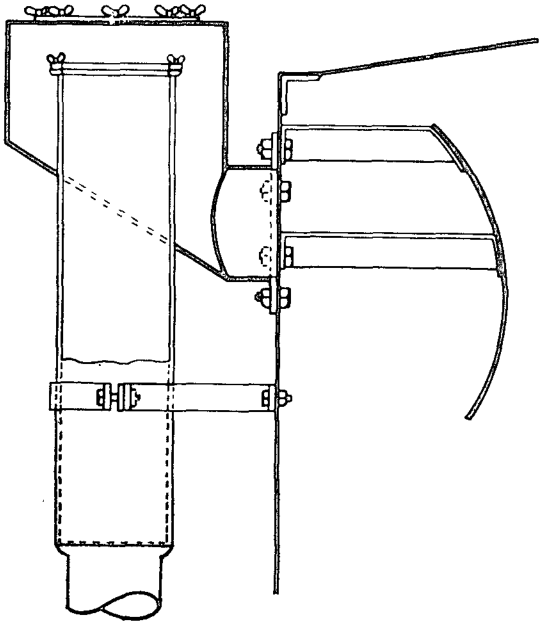


Figure A-3-1.2.3 Air foam chamber with Type II outlet.

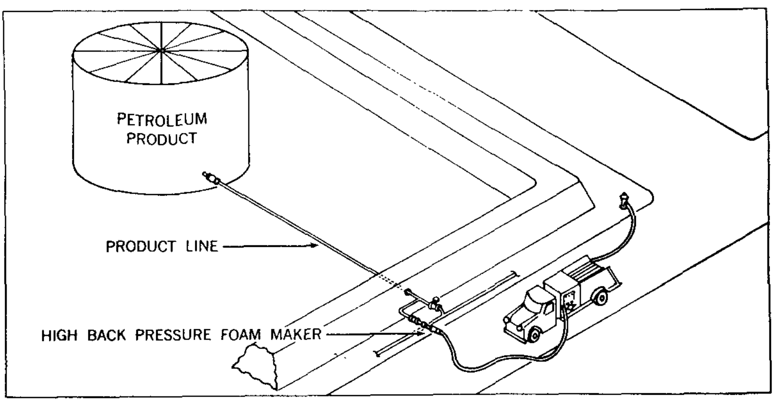


Figure A-3-1.2.4 Semi-fixed subsurface foam installation.

A-3-1.2.6 Semi-fixed Installations. These systems may be less practical than fixed systems, particularly where large tanks are involved. A relatively large crew, well trained in the use of the apparatus, is needed. Adequate facilities to transport the equipment and a good road system throughout the property are necessary.

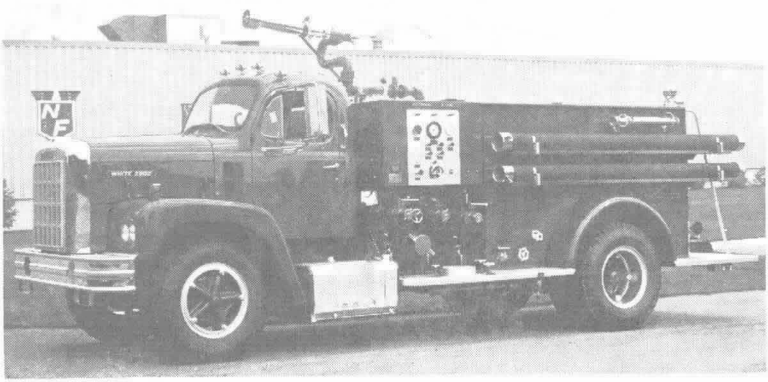
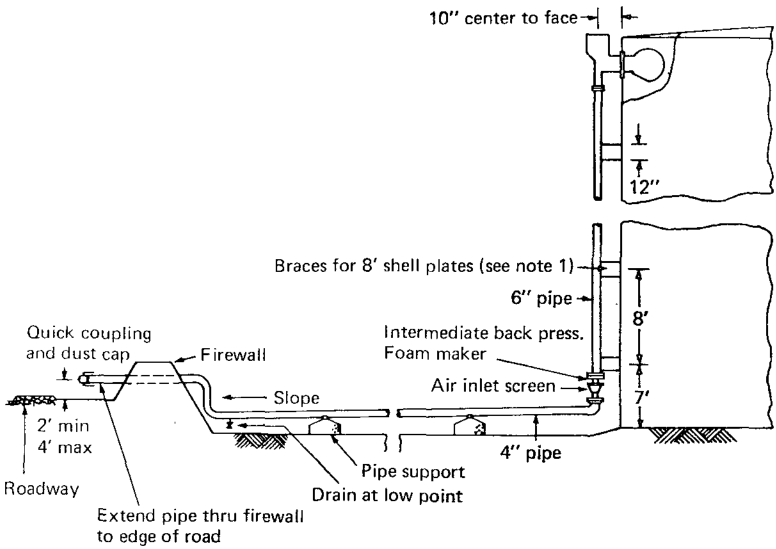


Figure A-3-1.2.6(a)(1) Typical foam truck complete with water pump, proportioning system, air foam concentrate tank and monitor nozzle.

TYPICAL AIR FOAM PIPING FOR INTERMEDIATE
BACK PRESSURE FOAM SYSTEM



Note 1
One brace (½" plate, 12" 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.

For SI UNITS
1 in. = 25.4 mm
1 ft. = 0.305 m

Figure A-3-1.2.6(a)(2) Typical air foam piping for intermediate back pressure foam system.

A-3-2.1.2 Rate of Application — Water Soluble Solvents. The system should be designed in the basis of fighting a fire in but 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 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 x 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 x 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 stocks, as well as for mixed solvents, should be selected with due regard to the foam breaking properties of the mixture.

A-3-2.1.3 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 about six times the rated capacity (in gpm) of the nozzle.

A-3-4.6 In general the foam system may be designed on the basis that only a single tank is involved in any one fire. The quantity of foam-producing materials required shall be based on the "worst risk" in the group of tanks to be protected; i.e., with due consideration to the factors of liquid surface area, rate of application, contents and type of foam discharge outlet used.

A-3-5.1.1 It may be deemed advisable to install a proper 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-3-5.1.1(a) and A-3-5.1.1 (b) are typical fixed foam discharge outlets or foam chambers.

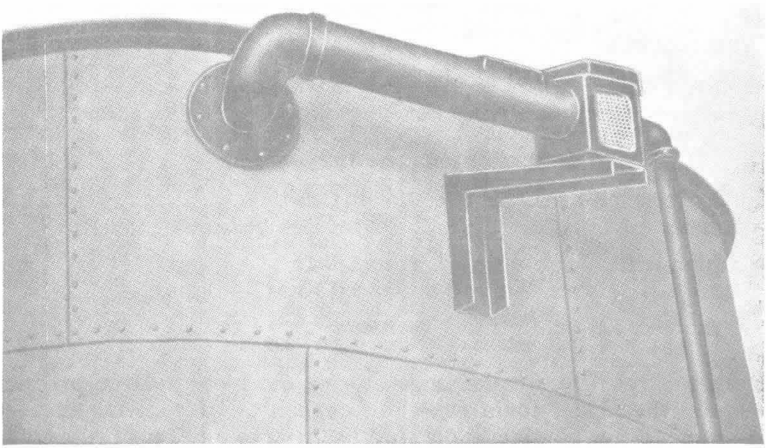


Figure A-3-5.1.1(a) Air foam maker in horizontal position at top of storage tank.

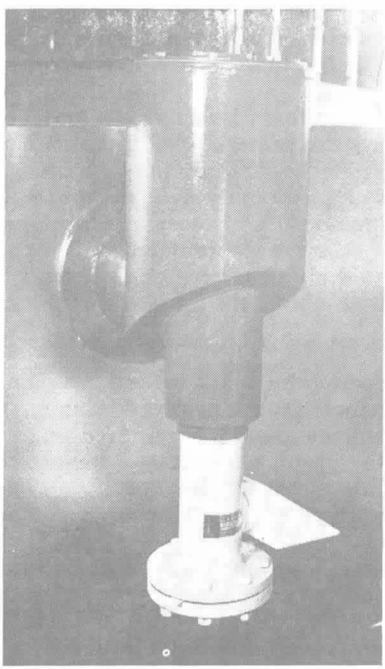


Figure A-3-5.1.1(b) Foam chamber and foam maker.

A-3-5.1.2 Open Top Floating Roof Tanks. Within the scope of this standard, tanks without fixed roofs are open top tanks which 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 B.*) The design is furnished with a pantograph type seal or a tube seal with metal weather shield. [*See Figures A-3-5.1.2(a) and A-3-5.1.2 (b).*] Plastic blankets, floating diaphragms or closures which are easily submerged are not included in this definition. Tanks so equipped should be treated as fixed roof tanks.

Two techniques are available for application of foam from fixed outlets. One involves discharge of foam above the pantograph seal or the metal weather shield. The other involves discharge of foam below the pantograph seal directly onto the flammable liquid surface or behind the metal weather shield directly on the tube seal envelope and the flammable liquid surface depending on tube seal damage.

Fixed foam fire fighting systems may be either manually or automatically operated or capable of both type operations. The design can utilize a fixed installation or, if manual, a semi-fixed installation.

(a) When it is desirable to provide fixed foam discharge devices above a pantograph-type continuous fabric seal or above the metal weather shield of a tube seal, the following may be used as a design guide.

1. A circular dam made of at least No. 10 US Standard Gage thickness (0.134 inches [3.40 mm]) steel plate should be welded or otherwise securely fastened to the floating roof. The purpose of the dam is to retain the foam at the seal area and to provide for sufficient depth (12 inches [305 mm] minimum) to cause the foam to flow laterally to a point where the seal may have been ruptured. The dam should be slotted at the bottom to provide for drainage of rain water. Total drain slot areas should be 0.04 square inch per square foot (278 mm^2/m^2) if diked area, and the slots should be approximately ⅜ inch (9.5 mm) high. The foam dam should be at least 1 foot (0.3 m) and not more than 2 feet (0.6 m) from the edge of the roof. [*See Figure A-3-5.1.2(c).*]

2. Precaution should be taken to prevent mechanical interference of foam devices and piping with the floating roof, the seal or weather shield and rolling ladder.

3. The number of points of foam application are to be determined by the circumference of the tank. The maximum spacing between applicators should be 40 ft. (12.2 m) of tank circumference using a 12 inch (305 mm) high dam and 80 ft. (24.4 m) of tank circumference using a 24 inch (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-7-1.1(g)*].

4. Rate of application and supply of foam liquid should be calculated using the area of annular ring between the circular dam and the tank shell. The minimum solution rate should be 0.16 gpm per square foot (6.5 *l*/min·m²). The supply of foam liquid should be adequate to operate the system for 20 minutes.

(b) When it is desired to provide fixed foam discharge devices below the pantograph type fabric seal, or the metal weather shield of a tube seal design, the following may be used as a design guide.

1. With the pantograph type fabric seal the maximum spacing between applicators should be 130 feet (39.7 m) measured around the circumference of the tank and a circular foam dam is not required.

2. With the tube seal design the maximum spacing between applicators should not be more than 60 feet (18.3 m) measured around the circumference of the tank. If the distance between the top of the tube seal and the top of the pontoon desk is less than 6 inches (152 mm), a circular foam dam is required. The dam should be at least 12 inches (305 mm) high, installed on the top of the deck, adjacent to the weather shield.

3. The foam should be a low expansion type usually associated with drainage times near the lower acceptable limit [*see Figure A-7-1.1(g)*].

4. Precaution should be taken to prevent mechanical interference of foam devices or piping with the floating roof, seal linkages or rolling ladder.

5. When a foam dam is not required, the rate of application and the supply of foam liquid should be calculated using the area of the annular ring between the tank shell and the floating roof edge. The minimum rate should be 0.5 gpm per square foot (20.4 *l*/min·m²) of area. The supply should be adequate to operate the system for 10 minutes.

6. When a foam dam is required, the rate of application and the supply of foam liquid concentrate should be calculated using the area of the annular ring between the tank shell and the dam. The minimum rate should be 0.16 gpm/ft.² (6.5 *l*/min·m²) of area. The supply should be adequate to operate the system for 20 minutes.

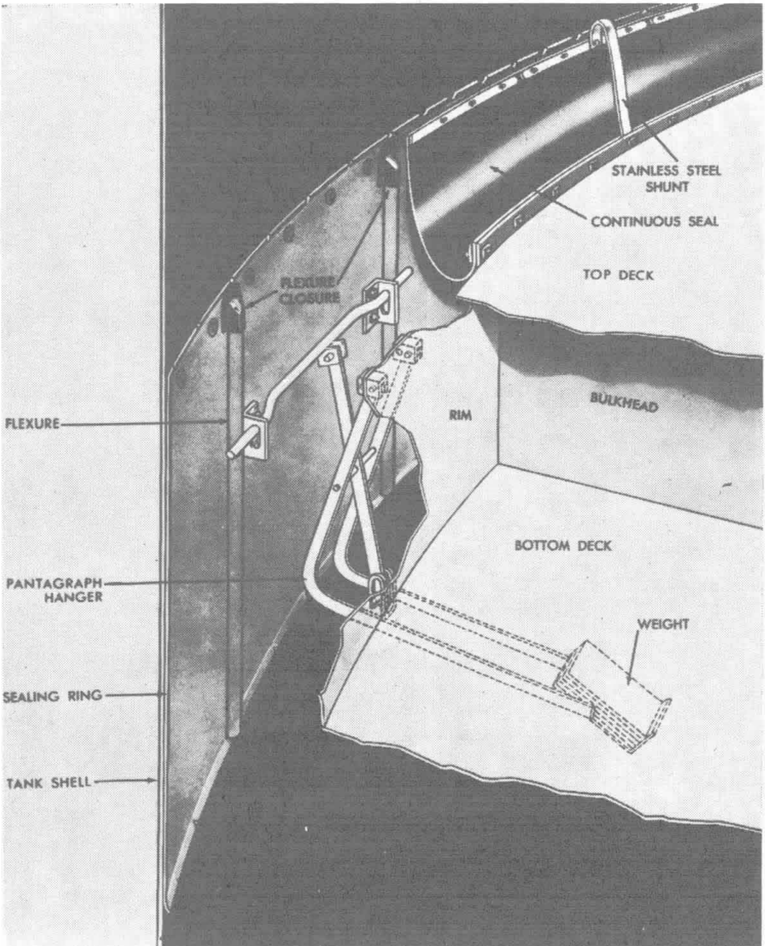


Figure A-3-5.1.2(a) Pantograph type seal-open top floating roof tank.

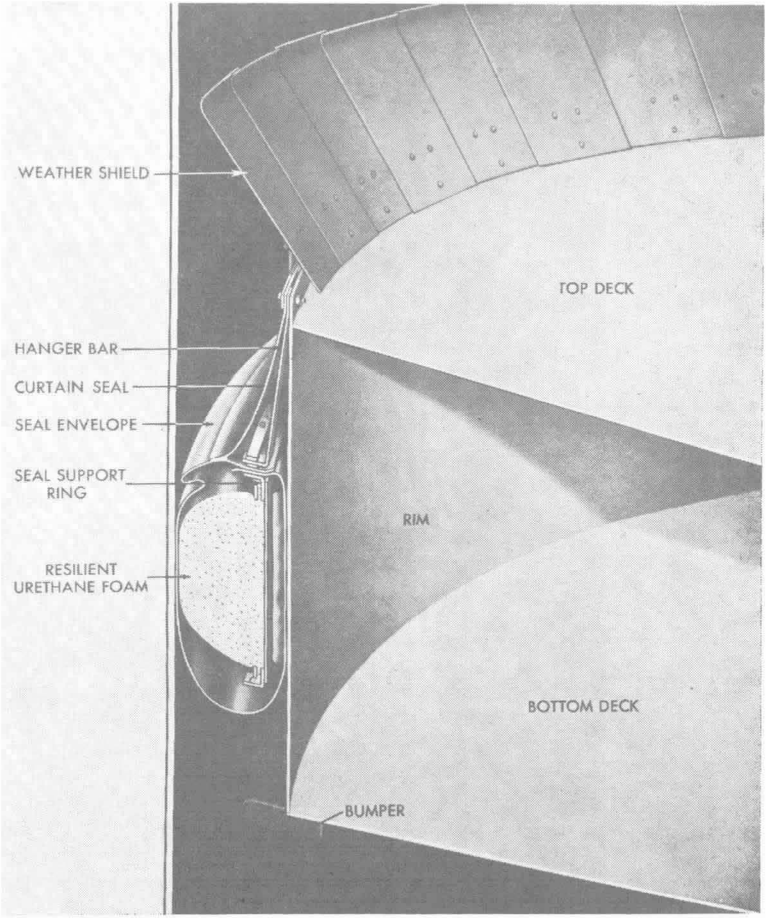


Figure A-3-5.1.2(b) Tube seal-open floating roof tank.

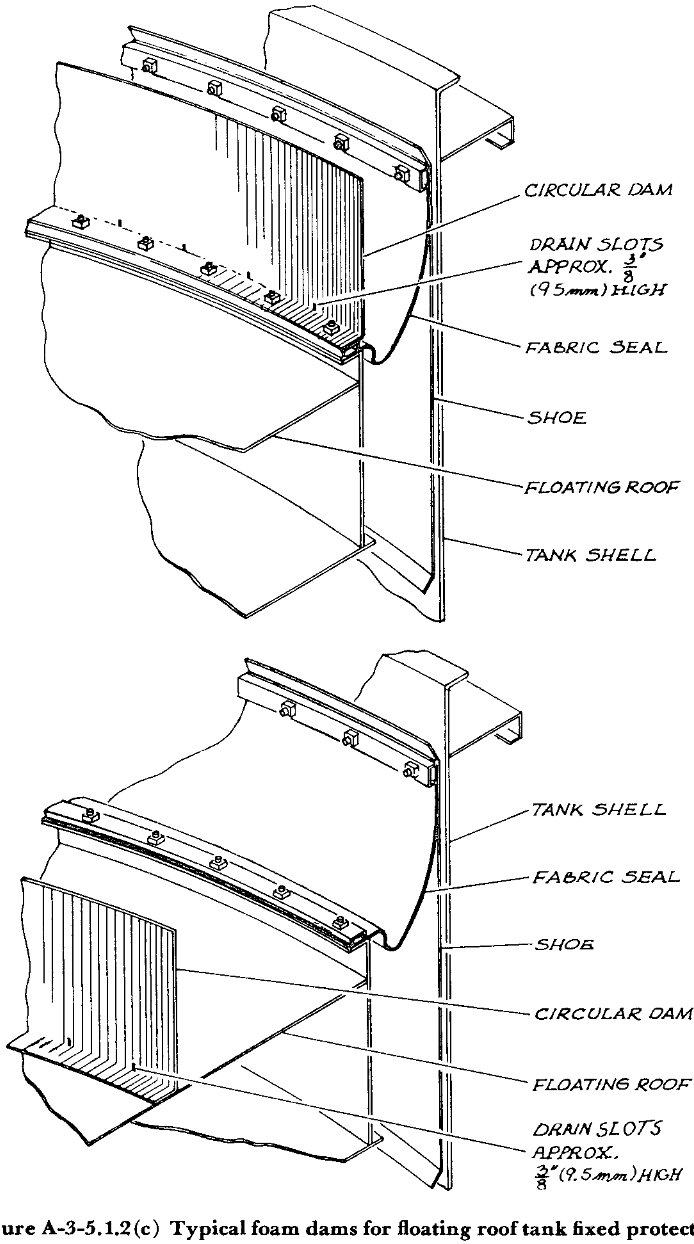


Figure A-3-5.1.2(c) Typical foam dams for floating roof tank fixed protection.

A-3-5.1.3 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*. (*See Appendix B.*)

(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 for other than floating roof tanks, except that separately valved laterals for each foam discharge device are not required. Subsurface or semi-subsurface methods are not recommended because of the possibility of improper distribution of foam.

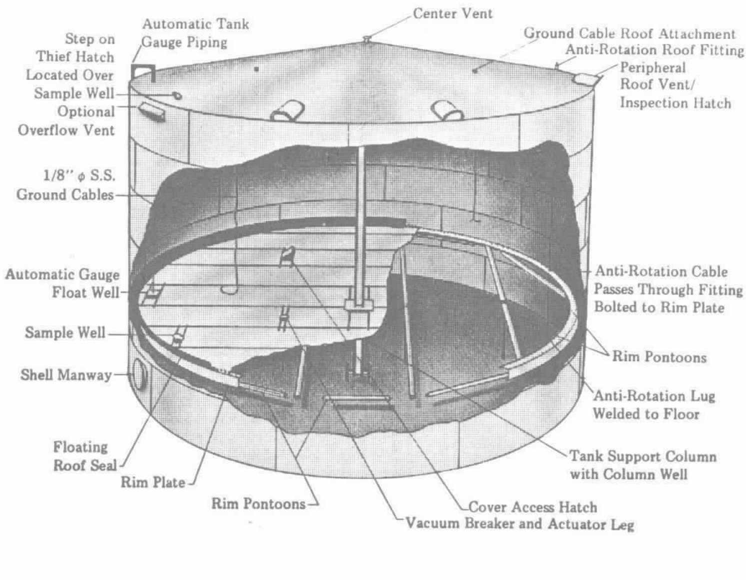


Figure A-3-5.1.3 Typical covered floating roof tank.

(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*. (*See Appendix B.*) 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-3-5.1.2.

(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 for other than floating roof tanks.

A-3-5.1.4 Fixed foam protection may be desirable for common diked areas surrounding multiple tanks with less than NFPA 30 (*see Appendix B*) spacing 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 Chapter 6.

For fixed or oscillating monitors, use a solution application rate of 0.16 gpm/ ft.^{2} (6.5 *l*/min·m^2) with supplies of foam-producing materials as for fixed outlets above. It is not necessary to apply foam simultaneously to the total diked area as long as monitor reach will provide adequate coverage.

For protection of diked areas which 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 table in Chapter 3 under "Tanks Containing Other Flammable and Combustible Liquids Requiring Special Foams." Supplies of foam-producing materials should be provided for 30 minutes application.

A-3-5.2.1 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 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 liquids with flash points higher than average product temperature, this turbulent area fire is self-extinguishing as cool product is rolled to the surface and nearby hot shell surfaces are cooled. With low flash point Class IB liquids the fire over the turbulent area will continue until it is adequately covered by foam. Depending on local circumstances, it may be possible to extinguish any residual flickers over the turbulent area by use of 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 which 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 for liquids which do not form a heat wave, pump rate should be continuous. 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.

A-3-5.2.3 Foam-producing Materials and Equipment. Optimum foam characteristics for subsurface injection and purposes are expansions between 2 and 4, 25 percent drainage time minimum of 90 seconds, and no more than 75 percent of the water shall drain out in 10 minutes when measured at atmospheric pressure on samples taken from the foam inlet line at the base of the tank. The procedures specified in A-7-1.1 should be followed.

A-3-6.2 (a) **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-3-6.2(a) through A-3-6.2(d) are based on a foam of expansion 4 which is the value to be used for friction loss and inlet velocity calculations.

(b) **Chemical Foam Friction Loss Through Piping.** For single line chemical foam generator systems, the following table, based on 100 lbs. per square inch (690 kPa) indicated flow pressure at the generator inlet, will serve as a guide to the sizes and lengths of piping which may be used:

	FOAM PIPE LINES ALONE		**FOAM PIPE LINES IN COMBINATION WITH FOAM HOSE LINES**			
Approximate Rate of Foam Production at 100 psi Generator Inlet Pressure gpm	**Min. Pipe Size Inches**	**Max. Length Feet**	**Min. Pipe Size Inches**	**Max. Length of Pipe Feet**	**Max. Length of Hose Feet**	**Min. Hose Diam. Inches**
Up to 400	2	150	2	100	50	1½
Over 400 to 1200 . .	3	200	3	150	50	2½
	or					
	4	400	4	350	50	2½
Over 1200 to 2200 .	4	400	4	350	50	2½
	or					
	6	600	6	550	50	2½

For SI UNITS
1 gpm = 3.785 l/min
1 psi = 6.895 kPa
1 ft = 0.305 m
1 in. = 25.4 mm

NOTE: Where other generator inlet pressures prevail the authority having jurisdiction should be consulted. Where greater discharge rates or pipe lengths or smaller pipe sizes are proposed, tests should be made to determine the foam quality resulting, and test data should be submitted to the user and to the authority having jurisdiction.

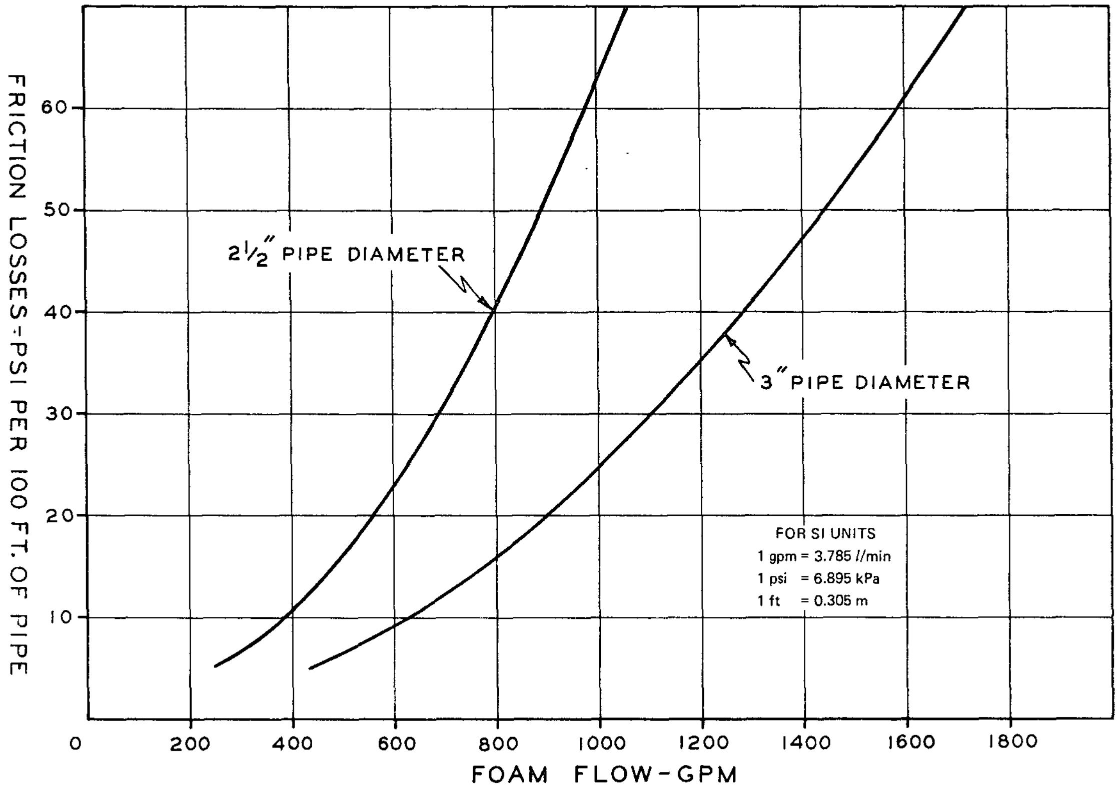


Figure A-3-6.2(a)

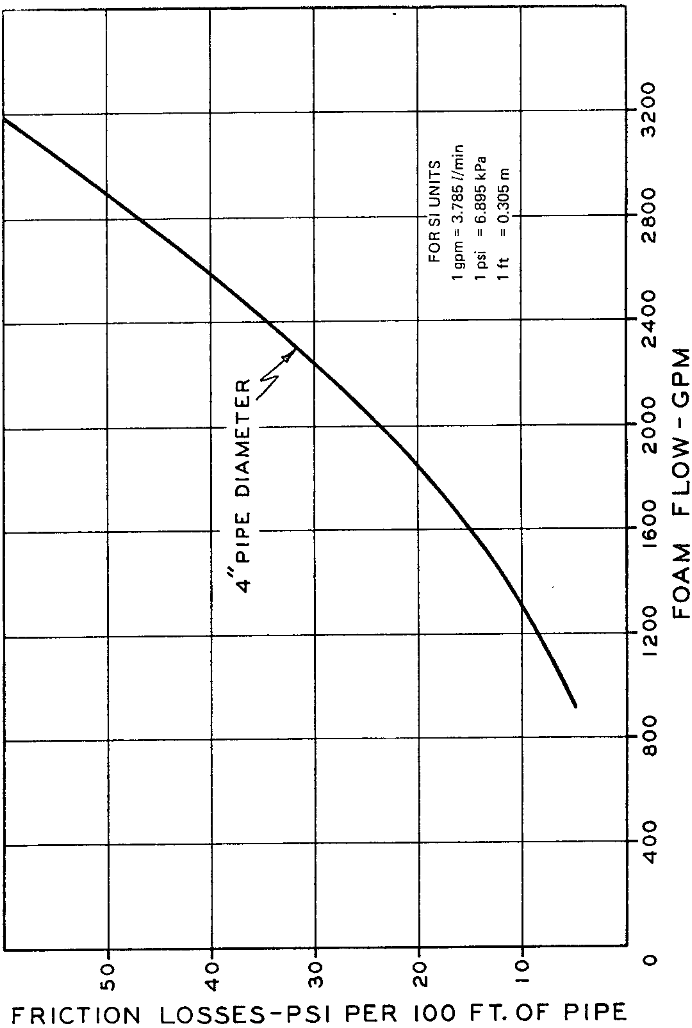


Figure A-3-6.2(b)