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DELUGE FOAM-WATER SPRINKLER AND SPRAY SYSTEMS 1980

NATIONAL FIRE PROTECTION ASSOCIATION, INC.
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Standard for the Installation of Deluge Foam-Water Sprinkler Systems and Foam-Water Spray Systems

NFPA 16-1980

1980 Edition of NFPA 16

This 1980 edition of NFPA 16, *Standard for the Installation of Deluge Foam-Water Sprinkler Systems and Foam-Water Spray Systems*, was prepared by the Technical Committee on Foam-Water Sprinklers and was adopted by the National Fire Protection Association, Inc. on November 20, 1980 at its Fall Meeting in San Diego, California. It was released for publication by the Standards Council on December 10, 1980.

It has been approved by the American National Standards Institute.

This edition has been completely rewritten according to the NFPA Manual of Style and equivalent SI units have been added to the customary units.

Origin and Development of NFPA 16

A Standard for Combined Foam and Water Spray Systems was originally published in 1954 by the National Board of Fire Underwriters (now American Insurance Association). In 1959, the National Fire Protection Association, with the cooperation of the National Board and other interested groups, established a committee on Foam-Water Sprinklers to update and expand the coverage, and the first official NFPA standard was adopted in 1962. Further amendments were made in 1968, 1974, and 1980.

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Standard for the Installation of Deluge Foam-Water Sprinkler Systems and Foam-Water Spray Systems

NFPA 16-1980

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

Information on referenced publications can be found in Appendix B.

Foreword

The uses of air foam (or mechanical foam as it was first called) for fire protection have expanded greatly since its inception in the 1930s. Original applications of this agent utilized a proteinaceous-type liquid foam forming concentrate delivered in water solution to a turbulence-producing foam generator or nozzle which then directed the mechanically formed air foam to a burning fuel tank or area of burning flammable fuel. (Details of these and similar applications are found in NFPA 11, 402, and 403.) As the technology for using this agent developed over the years, new systems and new devices for applying the foam to the hazard being protected and new foam forming liquid concentrates were proven useful for fire protection purposes. The application of foam from overhead sprinkler type systems using especially designed foam-making nozzles capable of either forming a foam from protein-type foam concentrate solutions or delivering a satisfactory water discharge pattern when supplied with water only was an early development (ca. 1954) in foam fire protection. Protein, fluoroprotein, and aqueous film forming concentrates (as defined in NFPA 11) are suitable for use with foam-water sprinklers. This latter type of foam concentrate has also been found to be suitable for use with standard sprinklers of the type referred to in NFPA 13, when the system is provided with the necessary foam concentrate proportioning equipment. Care must be exercised to ensure that the choice of concentrate and discharge device are listed for use together.

This standard is based on available test data and design experience concerning the design information, installation recommendations, operating methods and maintenance needs for the above types of foam-water sprinkler systems and foam-water spray systems utilizing protein, fluoroprotein, or aqueous film forming foam concentrates. These systems possess the common characteristic of being capable of either discharging air foam in a spray form or discharging water in a satisfactory pattern for fire protection purposes.

Chapter 1 General Information

1-1 Scope.

1-1.1 This standard covers the minimum requirements for open head deluge-type foam-water sprinkler systems and foam-water spray systems, each of which combines in a single system provision for the alternate discharge of air foam or water.

1-1.2 Accordingly, systems may be designed with the required density for either foam or water application as the controlling factor, depending on the design purpose of the protection.

1-1.3 The devices covered herein are intended primarily for use in foam-water deluge sprinkler systems, or foam-water spray systems. This standard is not applicable where separate foam, water sprinkler or water-spray fixed systems are to be installed. Reference should be made to either NFPA 11, *Standard for Foam Extinguishing Systems*; NFPA 13, *Standard for the Installation of Sprinkler Systems*; NFPA 15, *Standard on Water Spray Fixed Systems for Fire Protection*; or NFPA 11B, *Standard on Synthetic Foam, Combined Agent Systems*.

1-2 Purpose. The purpose of this standard is to provide a reasonable degree of protection for life and property from fire through installation requirements for foam-water deluge sprinkler systems and foam-water spray systems based upon sound engineering priciples, test data, and field experience.

1-3 Definitions.

Air Foam. Air foam is an aggregation of air-filled bubbles of lower specific gravity than flammable liquids or water. In the cases of the systems covered by this standard, it extinguishes fires by resisting flame and heat attack in the process of falling from an overhead sprinkler-type system where it is formed initially to a burning flammable or combustible liquid surface where it flows freely, progressively removing heat and forming an air-excluding continuous blanket or film over the fuel, thus sealing volatile combustible vapors from access to air or reignition. The air foam produced by these systems possesses qualities of lower expansion, higher fluidity, and more rapid foam solution drainage than foams useful in other circumstances. (*See NFPA 11, Standard for Foam Extinguishing*

Systems; NFPA 402, Recommended Practice for Aircraft Rescue and Firefighting Operational Procedures for Aircraft Fire Departments; NFPA 403, Recommended Practice for Aircraft Rescue and Fire Fighting Services at Airports and Heliports; and NFPA 412, Standard for Evaluating Foam Fire Fighting Equipment on Aircraft Rescue and Fire Fighting Vehicles.)

Air Foam Concentrates. There are three principal types of liquid foam forming concentrates useful for incorporation in the systems covered by this standard:

(a) Protein-Foam Concentrates: These foam concentrates consist primarily of products from a protein hydrolysis plus stabilizing additives and inhibitors. Current formulations are available for use at recommended nominal concentrations of 3 percent or 6 percent by volume of the solution discharge of the system.

(b) Fluoroprotein-Foam Concentrates: These concentrates are very similar to protein-foam concentrates as described above but with a synthetic fluorinated surfactant additive. They form an air-excluding foam blanket and may also deposit a vaporization-inhibiting film on the surface of a liquid fuel. These concentrates are used at recommended nominal concentrations of 3 percent and 6 percent of the solution discharge of the system.

(c) Aqueous Film Forming Foam (AFFF) Concentrates: These foam concentrates consist of a fluorinated surfactant with suitable foam stabilizers and additives. Foams formed from these concentrates act as a barrier to exclude air or oxygen and develop aqueous films on the fuel surface capable of suppressing the evolution of fuel vapors. Current formulations are available for use at recommended nominal concentrations of 3 percent or 6 percent by volume of the solution discharge of the system.

Air Foam Solution. A mixture consisting of an air foam concentrate in suitable proportions in either fresh or salt water.

Approved. "Acceptable to the authority having jurisdiction."

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

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

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

Discharge Devices. There are three principal types of discharge devices which are installed at the discharge outlets of the systems covered by this standard.

(a)* Foam-Water Sprinklers: These discharge devices are especially designed, open-type air-aspirating heads consisting of an open barrel body foam maker which terminates in a deflector to shape the pattern of the foam or water issuing from the assembly. These devices produce water discharge patterns closely comparable to those of standard sprinklers (*see NFPA 13, Standard for the Installation of Sprinkler Systems*) when discharging at the same rates of flow.

(b)* Foam-Water Spray Nozzles: These are also air-aspirating discharge devices, but they differ in design from foam-water sprinklers. They distribute foam, or water, in a special directional pattern peculiar to the particular nozzle.

(c) Standard Sprinklers: These discharge devices are the standard sprinklers, without heat responsive elements, referred to in NFPA 13, *Standard for the Installation of Sprinkler Systems*, and they are non-air-aspirating. When they are supplied with aqueous film forming foam (AFFF) air foam solution, a foam discharge pattern is produced closely conforming to the water discharge pattern of these sprinklers.

Foam-Water Sprinkler System. A foam-water sprinkler system is a special system pipe-connected to a source of air foam concentrates and to a water supply, and equipped with appropriate discharge devices for extinguishing agent discharge and for distribution over the area to be protected. The piping system is connected to the water supply through a control valve which is usually actuated by operation of automatic detection equipment installed in the same

areas as the sprinklers. When this valve opens, water flows into the piping system, air foam concentrate is injected into the water, and the resulting air foam solution discharging through the discharge devices generates and distributes air foam. Upon exhaustion of the air foam concentrate supply, water discharge will follow the air foam and continue until shut off manually. Systems may be used for discharge of water first, followed by discharge of air foam for a definite period and this followed by water until manually shut off. Existing deluge sprinkler systems which have been converted to the use of aqueous film forming foam are classed as Foam-Water Sprinkler Systems.

Foam-Water Spray System. A foam-water spray system is a special system pipe-connected to a source of air foam concentrate and to a water supply, and equipped with foam-water spray nozzles for extinguishing-agent discharge (air foam or water sequentially in that order or in reverse order) and distribution over the area to be protected. System-operation arrangements parallel those for foam-water sprinkler systems as described in the foregoing paragraph.

Density. This term refers to the unit rate of liquid application to an area and is expressed in gal per min per sq ft. The term "density" is used in this standard with reference to application of water in some cases and in others to application of air foam solution.

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

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

Shall. Indicates a mandatory requirement.

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

1-4 System Design.

1-4.1 Automatic operation supplemented by auxiliary manual tripping means is preferred, but manual operation may be acceptable.

1-4.2 Systems shall deliver air foam for a definite period at given densities (gal per min of air foam solution per sq ft) [(L/min)/m²] to the hazards which they protect, either prior to water discharge or following water discharge, depending upon system-design purpose.

1-4.3 Following completion of discharge of air foam to the hazards protected, these special systems shall discharge water until manually shut off.

1-4.4 Authorities having jurisdiction shall be consulted as to the means by which a reserve supply of air foam concentrate shall be made available. The purpose of a reserve supply of concentrate is to have available the means for returning systems to service-ready condition following system operation. Reserve supply shall be listed for use with system components (*see 2-1.2.3*).

1-5 Applicability.

1-5.1 Systems of this type shall discharge air foam or water from the same discharge devices. In view of this dual extinguishing agent discharge characteristic, these systems are selectively applicable to combination Class A and Class B hazards, as defined in NFPA 10, *Standard for Portable Fire Extinguishers*.

NOTE: Caution must be exercised when auxiliary extinguishing equipment is used with these systems. Some extinguishing agents may be incompatible with some air foams.

1-5.2 Foam-water deluge systems are especially applicable to the protection of most flammable-liquid hazards. They may be used for any of the following purposes or combinations thereof:

(a) Extinguishment. The primary purpose of such systems is the extinguishment of fire in the protected hazard. For this purpose, suitable foam-solution discharge densities [gal per min per sq ft or (L/min)/m²] shall be provided by system design and use of selected discharge devices; and by provision of adequate supplies of air-water at suitable pressures to accomplish the system-design. Foam-discharge rates shall be suitable for the design period and following depletion of air foam concentrate supplies, to provide similar rates of water discharge from the system until shut off.

(b) Prevention. Prevention of fire in the protected hazard is a supplemental feature of such systems. Manual operation of a system to selectively discharge foam or water from the discharge devices in

case of accumulations of hazardous materials from spills in such occupancies as garages, aircraft hangars, petrochemical plants, paint and varnish plants, or from other causes in the protected area will afford protection against ignition pending clean-up measures. In such cases, manual system operation can provide for foam coverage in the area with water discharge manually available.

(c) Control and Exposure Protection. Control of fire, to permit controlled burning of combustible materials where extinguishment is not practicable, and exposure protection to reduce heat transfer from an exposure fire may be accomplished by water spray and/or foam from these special systems, the degree of accomplishment being related largely to the fixed discharge densities provided by the system design.

1-5.3 Foam of any type is not considered a suitable extinguishing agent on fires involving liquefied or compressed gases, e.g., butane, butadiene, propane, etc., nor on materials which will react violently with water (e.g., metallic sodium) or which produce hazardous materials by reacting with water, nor on fires involving electrical equipment where the electrical nonconductivity of the extinguishing agent is of first importance.

1-5.4 Some types of foam are not suitable for use on fires in water-soluble solvents and polar solvents. Special "alcohol-type" concentrates are available for production of air foams for protection of such hazards. These concentrates shall be specifically listed for this method of application.

1-6 Approvals.

1-6.1 Prior to designing a system under consideration, the authority having jurisdiction shall be consulted. All plans and specifications pertinent to the installation shall be approved by the authority having jurisdiction prior to installation and such authority shall be consulted as to devices and materials used in system construction and in selection of the air foam concentrate to be provided for system use. All equipment and concentrates shall be approved for the particular application intended.

1-7 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed in Table 1-7 with conversion factors.

Table 1-7

liter	L	1 gal = 3.785L
liter per minute per square meter	$(L/min)/m^2$	1 gpm/ft^2 = 40.746 $(L/min)/m^2$
millimeter per minute	1 mm/min	1 gpm/ft^2 = 40.746 mm/min
cubic decimeter	dm^3	1 gal = 3.785 dm^3
pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 105 Pa

For additional conversions and information, see ASTM E380, *Standard for Metric Practice*.

1-7.1 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.

1-7.2 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.

Chapter 2 System Components

2-1 Approved Devices and Materials. All components parts including air foam concentrates of foam-water spinkler and foam-water spray systems shall be listed.

2-1.1* Discharge Devices. Discharge devices may be air-aspirating, such as foam-water sprinkler and foam-water spray nozzles, or they may be non-air-aspirating, such as standard sprinklers.

2-1.1.1 Air-aspirating discharge devices may be used with all types of approved foam concentrates. Non-air-aspirating devices shall be used only with concentrates, such as AFFF, that have been tested and listed for use in these devices.

2-1.1.2 Discharge devices and foam concentrates shall be listed for use together.

2-1.2 Air Foam Concentrates.

2-1.2.1* Air foam concentrates shall be listed for use with the concentrate proportioning equipment and with the discharge device to be used. Replacement supplies of concentrates shall be checked by appropriate tests or otherwise to determine acceptability.

2-1.2.2 The quantities of air foam concentrates to be provided for foam-water sprinkler and spray systems shall be sufficient to maintain the discharge densities for the application time period used as a base in system design. (*See 1-4.4, 4-2.2 and 4-2.3.*)

2-1.2.3 There shall be a readily available supply of air foam concentrate sufficient to meet the design requirements of the system to put the system back in service after operation. This supply may be in separate tanks or compartments, in drums or cans on the premises, or available from an outside source within 24 hrs.

2-1.3 Air Foam Concentrate Proportioning Means.

2-1.3.1 Positive pressure-injection is the preferred method for introduction of air foam concentrates into the water flowing through the supply piping to the system.

2-1.3.2 Positive pressure-injection methods shall mean one of the following:

(a)* Air foam concentrate pump discharging through a metering orifice into the protection-system riser, with the foam pressure at the upstream side of the orifice exceeding the water pressure in the system riser by a specific design value.

(b)* A balanced-pressure proportioning system (demand type proportioner) utilizing an air foam concentrate pump discharging through a metering orifice into a proportioning controller (venturi) or orifice in the protection system riser, with the foam, liquid, and water pressures automatically maintained equal by the use of a pressure-control valve.

(c)* Pressure-proportioning tanks with or without a diaphragm to separate the water and foam concentrate.

2-1.3.3 Orifice plates shall have "tell-tale" indicators giving orifice diameters and indicating flow direction if flow characteristics vary with flow direction.

NOTE: See A-2-1.3.2(a) for formula for calculation of size of orifices used in metering air foam concentrates.

2-1.3.4 Where special conditions warrant, other proportioning methods may be used, such as around-the-pump proportioners and in-line inductors.

2-1.4* Pumps.

2-1.4.1 Air foam concentrate pumps and water pumps shall have adequate capacities to meet the maximum needs of the system on which they are used. (*See Section 3-2 for water supply requirements.*) To ensure positive injection of concentrates, the discharge pressure ratings of pumps at the design discharge capacity shall be suitably in excess of the maximum water pressure available under any condition at the point of concentrate injection.

2-1.4.2 Air foam concentrate pumps shall be carefully chosen and have adequate capacity for this special service and special attention shall be paid to the type of seals used with regard to the type concentrate being pumped.

2-1.4.3 Provision shall be made to shut off the air foam concentrate pump after the foam supply is exhausted.

2-1.5 Power Supply.

2-1.5.1 Power supply for the drivers of air foam concentrate pumps and water pumps shall be of maximum reliability. Compliance with the applicable requirements of NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, covering the reliability of power supply for fire-pump drivers, is considered as meeting the intent of this chapter.

2-1.5.2 Controllers governing the starting of air foam concentrate pumps shall be of approved types. Control equipment shall comply with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

2-1.6 Air Foam Concentrate Storage Tanks.

2-1.6.1 Storage tanks for air foam concentrates shall be of construction suitable for the liquid, solidly mounted, and permanently located.

2-1.6.2 Minimum storage temperatures of air foam concentrates shall be considered in locating storage tanks.

2-1.6.3 Storage tanks shall have capacities to accommodate only the needed quantities of air foam concentrate plus adequate space for thermal expansion, the latter to preferably be accomplished by means of a vertical riser or expansion dome. Tanks meeting this requirement will have minimum surface areas in contact with air and liquid concentrates at the liquid level and thus minimize the possibility of interior corrosion of tanks. Air foam concentrate outlets from tanks shall be raised above the bottoms of the tanks to provide adequate sediment pockets.

2-1.6.4 In determining the quantity of foam concentrates, the volume of the sediment pocket shall be added to the quantity needed for system operation.

2-1.6.5 Tanks shall be equipped with suitable conservation-type vents of adequate capacity; access handholes or manholes located to provide for inspection of interior tank surfaces, connections for pump suction; relief and testing lines; protected sight gages or other liquid-level devices; and adequate filling and draining connections.

2-1.6.6 Tanks shall be located to furnish a positive head on the pump suction.

2-1.6.7 Pressure proportioning tanks shall have means for filling, for gaging the level of concentrates and for drainage, cleaning and inspection of interior surfaces, and of the concentrate holding bag, if provided.

2-1.7 Pressure on Air Foam Concentrate Lines. Where air foam concentrate lines to the protective-system injection points are run underground or where they run aboveground for more than 50 ft (15 m), air foam 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.

2-1.8 Location of System-Control Equipment.

2-1.8.1 Equipment items, such as storage tanks and proportioners for air foam concentrates; pumps for water and air foam concentrates; and control valves for water, concentrates, and air foam solution 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.

2-1.8.2* 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.

2-1.9 Alarms.

2-1.9.1* A local alarm, actuated independently of water flow, to indicate operation of the automatic detection equipment shall be provided on each system. An alarm is not required on manually operated systems.

2-1.9.2* When an alarm is installed, the authority having jurisdiction shall be consulted regarding the alarm service to be provided and regarding the need for electrical fittings designed for use in hazardous locations in electric alarm installations (*see Article 500, NFPA 70, National Electrical Code®, and other articles in Chapter 5 thereof*).

2-1.9.3 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.

2-1.9.4 Alarm systems shall meet the applicable requirements of NFPA 72A, *Standard for the Installation, Maintenance and Use of Local Protective Signaling Systems*; NFPA 72B, *Standard for the Installation, Maintenance and Use of Auxiliary Protective Signaling Systems*; NFPA 72C, *Standard for the Installation, Maintenance and Use of Remote Station Protective Signaling Systems*; and NFPA 72D, *Standard for the Installation, Maintenance and Use of Proprietary Protective Signaling Systems*.

2-1.10 Strainers for Water and Air-Foam Concentrates.

2-1.10.1 Strainers shall be capable of removing from the water all solids of sufficient size to obstruct the discharge devices and listed for fire protection service. Strainers shall be installed so as to be accessible for cleaning during an emergency. Space shall be provided for basket removal.

2-1.10.2 Strainers shall be installed in the main water supply lines feeding orifices (or water passages) smaller than ⅜ in. (9.6 mm). Strainers shall be installed on systems having larger orifices where water supply conditions warrant. Normally ⅛-in. (3.2-mm) perforations are suitable.

2-1.10.3 Strainers shall be installed in liquid concentrate lines upstream of metering orifices or proportioning devices. Where listed strainers of the proper size are not available, strainers having a ratio of open-basket area to inlet pipe size of at least 10 to 1 shall be used.

Chapter 3 Water Supplies

3-1 Types of Water.

3-1.1* Water supplied to deluge foam-water sprinkler systems and foam-water spray systems may be fresh or salt, hard or soft, without affecting the quality or volume of foam produced. The water shall be free of constituents not compatible with air foam concentrates.

3-1.2 Water containing solids of size likely to clog orifices in discharge devices but otherwise acceptable from the foam-making standpoint shall be supplied to systems after passing through line strainers.

3-2 Water Supply Capacity and Pressure.

3-2.1 Water supplies for deluge foam-water sprinkler systems and foam-water spray systems shall be of capacity and pressure capable of maintaining foam discharge and/or water discharge at the design rate for the required period of discharge over the entire area protected by systems expected to operate simultaneously.

3-2.2 Where water supply is dependent on public water sources, attention shall be given to the pollution hazard introduced by the use of air foam concentrate and any cross connections cleared with Public Health Agencies concerned.

3-2.3 Water supplies shall be capable of supplying the systems at the design discharge capacity for at least 60 min.

Exception: For aircraft hangars, refer to NFPA 409 Standard on Aircraft Hangars.

Chapter 4 System Design and Installation

4-1 Plans and Specifications.

4-1.1 The designing and installation of deluge foam-water sprinkler and spray systems shall be entrusted to experienced and responsible persons. Before such systems are installed, complete working plans and specifications shall be prepared. Working plans shall be drawn to scale, show all essential details, and be easily reproduced. Working plans and specifications shall provide information on the discharge densities and period of discharge; hydraulic calculations; details of tests of available water supply, detailed layout of the piping and of the automatic detection equipment, type of discharge devices to be installed, and location and spacing of discharge devices; pipe-hanger installation details; location of draft curtains, and 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.

(a) In addition to the items listed in 4-1.1, plans and specifications shall indicate the quantity of air foam concentrate to be stored, including the quantity in reserve, and the concentration designation.

(b) The specifications shall indicate the specific tests to be conducted.

(c) 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.

(d) Charts showing head delivery, efficiency and brake horsepower curves of pumps shall be furnished by the contractor.

4-2 Design Guides.

4-2.1* Foam-water sprinkler and foam-water spray system designs shall conform to all the applicable requirements of the following standards of the National Fire Protection Association except where otherwise specified herein:

Title	NFPA Standard Number
Foam Extinguishing Systems	11
Synthetic Foam Combined Agent	11B
Sprinkler Systems	13
Standpipe and Hose Systems	14
Water Spray Fixed Systems for Fire Protection	15
Centrifugal Fire Pumps	20
Water Tanks for Private Fire Protection Service	22
Outside Protection	24
National Electrical Code	70
Central Station Protective Signaling Systems	71
Local Protective Signaling Systems	72A
Auxiliary Protective Signaling Systems	72B
Remote Station Protective Signaling Systems	72C
Proprietary Protective Signaling Systems	72D
Automatic Fire Detectors	72E

NOTE: Refer to NFPA occupancy standards where applicable.

4-2.2 The design discharge rates for water or air foam solution shall provide densities of not less than 0.16 gal per min per sq ft [6.5 (L/min)/m^2] of protected area.

Exception: For aircraft hangars refer to NFPA 409, Standard on Aircraft Hangars.

4-2.3 The foam discharge shall continue for a period of 10 min at the design rate specified in 4-2.2. If the system discharges at a rate above the minimum specified in 4-2.1, then the operating time may be reduced proportionately, but shall not be less than 7 min.

4-3 Piping, Valves, Pipe Fittings, and Hangers.

4-3.1 Applicable parts of Chapter 3 of NFPA 13, *Standard for the Installation of Sprinkler Systems*, 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 outdoor 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 the Installation of Sprinkler Systems*, are not applicable.

4-3.2* Pipe and fittings carrying air foam concentrate shall be of a material compatible with the particular air foam concentrate to be used.

4-3.3* All fittings shall be of a type specifically approved for fire protection systems and of a design suitable for the working pressures involved, but not less than 175 psi (12.1 bars) cold water pressures. Ferrous fittings shall be of steel, malleable iron or ductile iron in dry sections of the piping exposed to possible fire or in self-supporting systems. Galvanized fittings shall be used where galvanized pipe is required.

4-3.3.1 Rubber gasketed fittings may be used to connect pipe in fire exposed areas when the foam-water deluge system is automatically controlled. Fire exposed areas in which these fittings are located shall be protected by automatic foam-water deluge systems or other approved means.

4-4 Operating-Means Design.

4-4.1* In automatic systems the detecting equipment shall be connected to means for tripping water deluge valves and other system-control equipment. Supplemental manual means for accomplishment of this purpose shall also be provided.

4-4.2 In automatic systems air foam concentrate injection shall be activated automatically by, or concurrently with, activation of the main water-supply control valve. Manual operating means shall be designed to accomplish this same purpose.

4-4.3 Automatic detection equipment, whether pneumatic, hydraulic, or electric, shall be provided with complete supervision so arranged that failure of equipment, loss of supervising air pressure or loss of electric energy will result in positive notification of the abnormal condition.

4-4.4 Where used in a corrosive atmosphere, the devices shall be of materials not subject to corrosion or be protected to resist corrosion.

4-4.5 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 Article 500, NFPA 70, *National Electrical Code*, and other articles in Chapter 5 thereof.

4-4.6 In automatic systems, manually operated tripping devices shall actuate the automatic control valve by mechanical, pneumatic, electric, or other approved means. The manual device shall be strong enough to prevent breakage. Manual controls shall not require a pull of more than 40 lb [178 newtons (force)] nor a movement of more than 14 in. (356 mm) to secure operation.

4-5 Drainage. Facilities shall be provided for the safe removal or retention of the largest anticipated flammable liquid spill, plus the free water reaching the floor from the fixed fire protection system, as well as the discharge from hose streams.

4-6 Hydraulic Calculations.

4-6.1 System piping shall be hydraulically calculated and sized in order to obtain reasonably uniform foam and water distribution and to allow for loss-of-head in water-supply piping. The adjustment in pipe sizes shall be based on a maximum variation of 15 percent above the specified discharge rate per sprinkler or nozzle.

4-6.2 Pipe sizes shall be adjusted according to detailed friction-loss calculations. These calculations shall show the relation between the water supply and demand.

4-6.3 Hydraulic calculations for determining the air foam solution and water-flow characteristics of systems covered by this standard shall be in accordance with NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*. Piping carrying air foam solution shall be sized on the same basis as if it were carrying plain water.

4-6.4* The friction losses in piping carrying air foam concentrate shall be calculated using the Darcy formula (also known as the Fanning formula). Friction factors for use with this formula shall be selected from the charts, Friction Factors for Commercial Steel and Cast-Iron Pipe (*see A-1-3 for formula and Figures A-4-6.4(1)-(4) for charts*). In calculating Reynolds Number for selecting friction factors from the charts, the actual density (or specific gravity) of the air foam concentrate to be used in the system shall be used. The viscosity used shall be the actual viscosity of the air foam concentrate at the lowest anticipated storage temperature.

4-6.5 For purposes of computing friction loss in piping, the following "C" Factors shall be used for Williams and Hazens formula:

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

Chapter 5 Acceptance Tests

5-1 Flushing of Supply Piping.

5-1.1 Supply Piping. Underground mains and lead-in connections to system risers shall be flushed thoroughly before connection is made to system piping, in order to remove foreign materials which may have entered the underground during the course of the installations or which may have been present in existing piping. The minimum rate of flow shall be not less than the water demand rate of the system which is determined by the system design, or not less than that necessary to provide a velocity of 10 ft per sec (3 m/s), whichever is greater. For all systems the flushing operations shall be continued for a sufficient time to ensure thorough cleaning. When planning the flushing operations consideration shall be given to disposal of the water issuing from the test outlets.

Flow Required to Produce a Velocity of 10 Ft per Second (3 m/s) in Pipes

Pipe Size (Inches)	Flow (Gal per Minute)	(L/min)
4	390	1476
6	880	3331
8	1560	5905
10	2440	9235
12	3520	13 323

5-2 Hydrostatic Pressure Tests.

5-2.1 All piping, including yard piping, air foam concentrate lines and the system piping, shall be tested hydrostatically at not less than 200 lb per sq in. (13.8 bars) pressure for 2 hrs, or at 50 lb per sq in. (3.4 bars) in excess of the maximum static pressure when the maximum static pressure is in excess of 150 lb per sq in. (10 bars).

NOTE: It is recommended that air foam concentrate lines be tested using liquid foam concentrate as the testing medium.

5-2.2* The amount of leakage in underground water piping shall be measured at the specific test pressure by pumping from a calibrated container. Leakage shall not exceed 2 qts per hr (1.89 L/h) per 100 joints, irrespective of pipe diameter. See NFPA 24, *Standard for Outside Protection*, Chapter 8, Rules for Laying Pipe.

5-2.3 Air foam concentrate piping shall be shown to be leaktight during hydrostatic pressure tests.

5-3 System Tests Discharging Foam.

5-3.1* Acceptance tests shall include:

(a) Foam discharge from a single system.

(b) Simultaneous foam discharge of the maximum number of systems expected to operate on a single hazard.

(c) Where full flow tests are not practical, adequate tests of system components to verify design capability shall be performed.

5-3.2 The discharge shall be continued for a sufficient time period to obtain stabilized discharge.

5-3.3 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.

5-3.4* The concentration of foam liquid in solution shall be determined. During the tests, the pressure at the discharge devices shall be at least equal to the minimum design operating pressure of the system or systems tested. Percentage of all foam concentrates injected into the water shall be within the following limits: 3 percent to 4 percent for nominal 3 percent concentrates and 5 percent to 7 percent for nominal 6 percent concentrates. The rate of solution discharge may be computed from hydraulic calculations utilizing recorded inlet and/or end-of-system operating pressure. 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 shall be within the operating limit recommended by the authority having jurisdiction.

5-3.5 Systems shall be thoroughly flushed with water after operation with foam, except those portions normally containing air foam concentrate when the system is not operating.

NOTE: Give particular attention to strainers or other small openings.

Chapter 6 Periodic Testing

6-1 Testing and Inspection of Air Foam Concentrate Injection Systems. Air foam concentrate injection systems shall be so arranged that periodic tests and inspections are made without discharging air foam solution to the system piping in order to check operation of all mechanical and electrical components of the system. The system shall be so arranged that tests can be performed with as little loss of air foam concentrate as practical.

6-2* Inspection of Air Foam Concentrates. Periodic inspection shall be made of air foam concentrates and their containers for evidence of excessive sludging or deterioration. Inspection shall include a qualitative test of the air foam concentrate normally conducted by the manufacturer. Presence of specified quantities of concentrates in system-storage equipment in service-ready position and the quantities of reserve concentrates on hand shall be checked with requirements for same.

6-3 Tripping of Water-Control Valves. Water-supply control valves and their automatic and manual tripping means shall be trip tested semiannually. Tests shall be such that they may be accomplished without discharging air foam from system discharge devices or diminishing or diluting the air foam concentrate supply.

Chapter 7 Maintenance

7-1 Deluge Foam-Water Sprinkler and Foam-Water Spray Systems.

7-1.1* Systems shall be serviced by personnel experienced in this work at periodic intervals, preferably semi-annually, but at least annually.

7-1.2 Proportioning devices and strainers shall be thoroughly inspected and cleaned after each operation or flow test.

7-2 Operating and Maintenance Instructions and Layouts. Operating and maintenance instructions and layouts shall be readily available at the control equipment and at the plant fire headquarters. Selected plant personnel shall be trained and assigned the task of operating and maintaining the equipment.

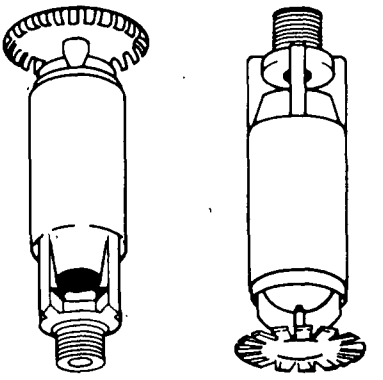
Chapter 8 Laboratory Tests for the Physical Properties of Foam

8-1 General. This chapter relates to the laboratory tests on foam concentrate and foam producing devices which are conducted by testing laboratories to correlate the foam quality with fire extinguishing characteristics.

8-1.1* Appendix A contains detailed laboratory procedures and references for the sampling and analysis of the fire fighting foam produced by the devices covered in this standard.

Appendix A

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



Upright Mounting Pendent Mounting

Figure A-1-3(a)

A-1-3 Foam-Water Sprinklers. Foam-water sprinklers are open-type sprinklers designed:

(a) To receive air-foam solution (water plus liquid concentrate);

(b) To direct the "solution" through an integral foam maker, the nozzle action of which breaks the "solution" into spray and discharges it into a mixing tube where it combines with air drawn in through openings in the housing;

(c) To provide mixing-chamber capacity for development of the air foam;

(d) To direct the formed foam discharging from the open end of the mixing tube against a deflector, shaped to distribute the foam in a pattern essentially comparable to the water-distribution pattern of present-day "standard" sprinklers (nomenclature from current edition of NFPA 13, *Standard for the Installation of Sprinkler Systems*), and to do this with essentially no impingement of the foam on the ceiling; and

(e) In the case of discharge of water only, that is, in absence of foam, to develop a water-distribution pattern directly comparable to that of "standard" sprinklers.

The normal direction of discharge from foam-water sprinklers is downward. To provide a choice in installation design, foam-water sprinklers are produced for installation in the upright position and in the pendent with the pattern of discharge in either case being that stated in the foregoing. Sprinkler deflectors shall be formed to produce the required discharge pattern which may mean differing shapes of deflectors for each of the two positions of installation. The variation in shape of deflectors is illustrated in Figure A-1-3(a).

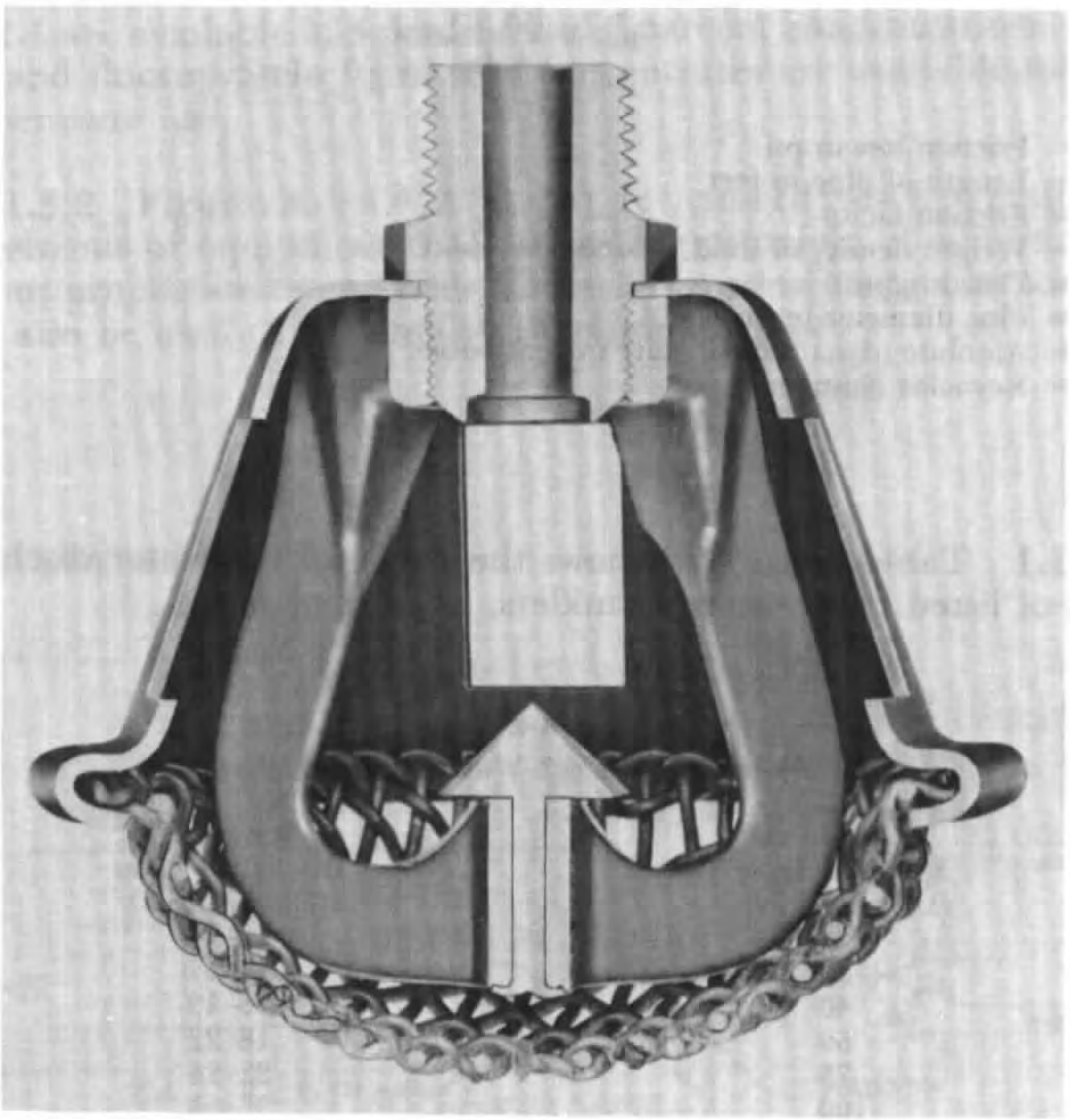


Figure A-1-3(b)

Foam-Water Spray Nozzles. Foam-water spray nozzles combine a foam-maker with a body and a distributing deflector. They will generate air foam in the same manner described for foam-water sprinklers, when supplied with air-foam solution under pressure, and will distribute the resulting foam, or water in the absence of foam solution, in a special pattern peculiar to the particular head.

These nozzles are available in a number of patterns with variations in discharge capacity.

Darcy Formula

$$\Delta P = 0.000216 \frac{fL\varrho Q^2}{d^5}$$

Reynolds Number

$$Re = \frac{50.6Q\varrho}{d\mu}$$

ΔP = Friction loss in psi
L = Length of pipe in feet
f = Friction factor
ϱ = Weight density of fluid, pounds per cubic foot
Q = Flow in gpm
d = Pipe diameter in inches
μ = Absolute (dynamic) viscosity in centipoise
Re = Reynolds Number

A-2-1.1 Table A-2.1.1(a) shows the range of the water discharge rates of listed foam-water sprinklers.

Table A-2-1.1(a)
Foam-Water Sprinkler* Water Discharge Rates

Pressure at Sprinkler Inlet (Lb per sq in.)	Range of Discharge Rates (Gal per min)
20	12-14
30	14-17
40	16-19
50	18-22
75	22-26
100	25-30

*Nominal ⅜ in. orifice

Table A-2-1.1(b)
Standard Sprinkler* Discharge Rates

Pressure At Sprinkler Inlet (Lb per sq in)	Range Of Disharge Rates (Gal per min)
7	14-16
10	16-19
20	23-26
30	28-32

*Nominal ½ in. orifice.

For SI Units
1 psi = 0.0689 bar
1 gpm = 3.785 L/min

A-2-1.2.1 Air foam concentrates meeting the requirements of 2-1.2.1 are available in 3 percent and 6 percent concentrations. Protein and fluoroprotein foam type concentrates are available for low temperature use.

A-2-1.3.2 Figures A-2-1.3.2 (a), (b), (c), and (d) are schematic arrangements of equipment to illustrate the principle of operation of various proportioning methods. Other arrangements or components may also be used to accomplish the same purpose.

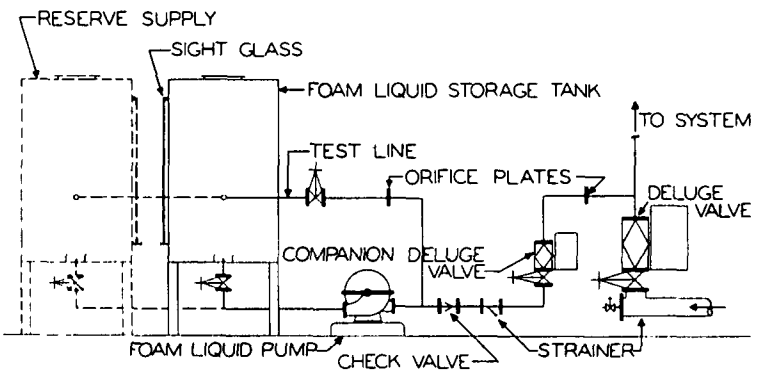


Figure A-2-1.3.2(a) Schematic arrangement of air-foam liquid-concentrate storage tank; liquid-concentrate pump; metering proportioner; and interconnecting piping.

NOTE: The air-foam liquid-concentrate metering orifice can be calculated by using the formula:

$$Q_f = KCd^2 \sqrt{\Delta P}$$

K = Constant of particular foam liquid concentrate (available from the manufacturer)
C = Orifice constant
d = Diameter of orifice in inches
ΔP = Pressure differential across the orifice plate
Q_f = Volume of foam liquid concentrate gpm

The coefficient "C" is affected by several factors which include orifice shape, viscosity of foam liquid, velocity, ratio of orifice diameter to pipe diameter, etc.

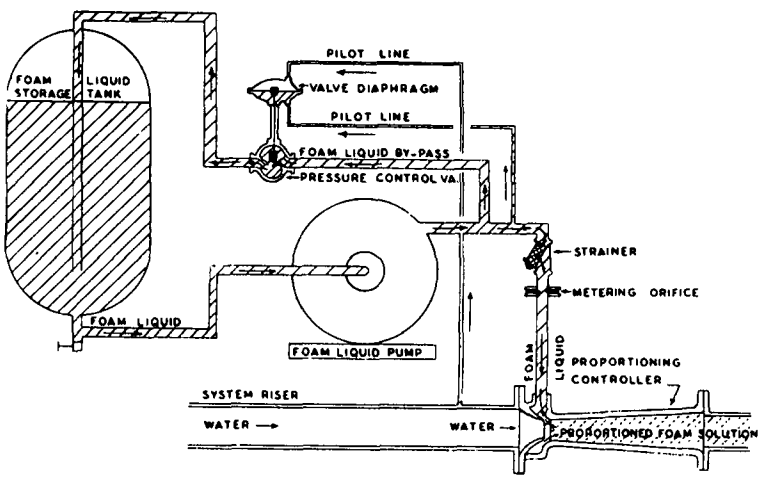


Figure A-2-1.3.2(b)
Balanced-Pressure Proportioning System

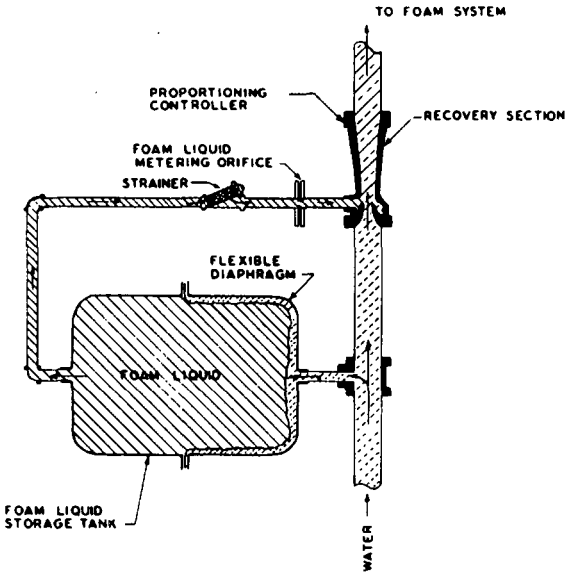


Figure A-2-1.3.2(c) Pressure-Proportioning Tank With Diaphragm

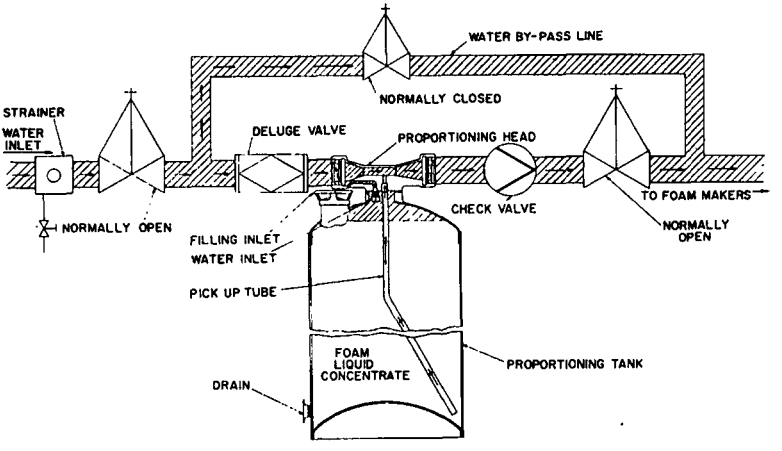


Figure A-2-1.3.2(d) Pressure-Proportioning Tank Method (Pressure-Proportioning Tank Without Diaphragm.) The arrangement of these devices may take a variety of forms. A single tank or a battery of tanks manifolded together may be used.

A-2-1.4 Air foam concentrate pumps should have reliability equivalent to that of approved fire pumps.

A-2-1.8.2 Consideration should be given to provisions of remotely located post-indicator or other shutoff valves to permit system water supply control under abnormal conditions.

A-2-1.9.1 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, the nearest fire department station or other suitable place where aid may be readily secured. Central station or proprietary station water flow alarm service is desirable but provision of this service does not necessarily waive the local alarm requirement.

A-2-1.9.2 See NFPA 71, *Standard on 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*. Outdoor water-motor or electric-alarm gongs, responsive to system water flow, may be required.

A-3-1.1 Fire fighting efficiency of air foams is not significantly affected when water temperature is below approximately 100°F (38°C), although some reduction in expansion occurs with very cold water. If the water temperature exceeds 100°F (38°C), however, foam stability and fire fighting efficiency usually is reduced.

A-4-2.1 For supervision of valves, refer to NFPA 26, *Recommended Practice for the Supervision of Valves Controlling Water Supplies for Fire Protection*.

A-4-3.2 It has been noted that galvanized piping is not compatible with most foam liquids.

A-4-3.3 Rubber gasketed fittings subject to direct fire exposure are generally not suitable. Where necessary for piping flexibility or for locations subject to earthquake, explosion or similar hazards, such installations are acceptable. In such cases special hanging or bracing may be necessary.

A-4-4.1 The spacing of automatic detection equipment for systems installed for protection against fire exposure may call for a different arrangement from that required for other types of systems.

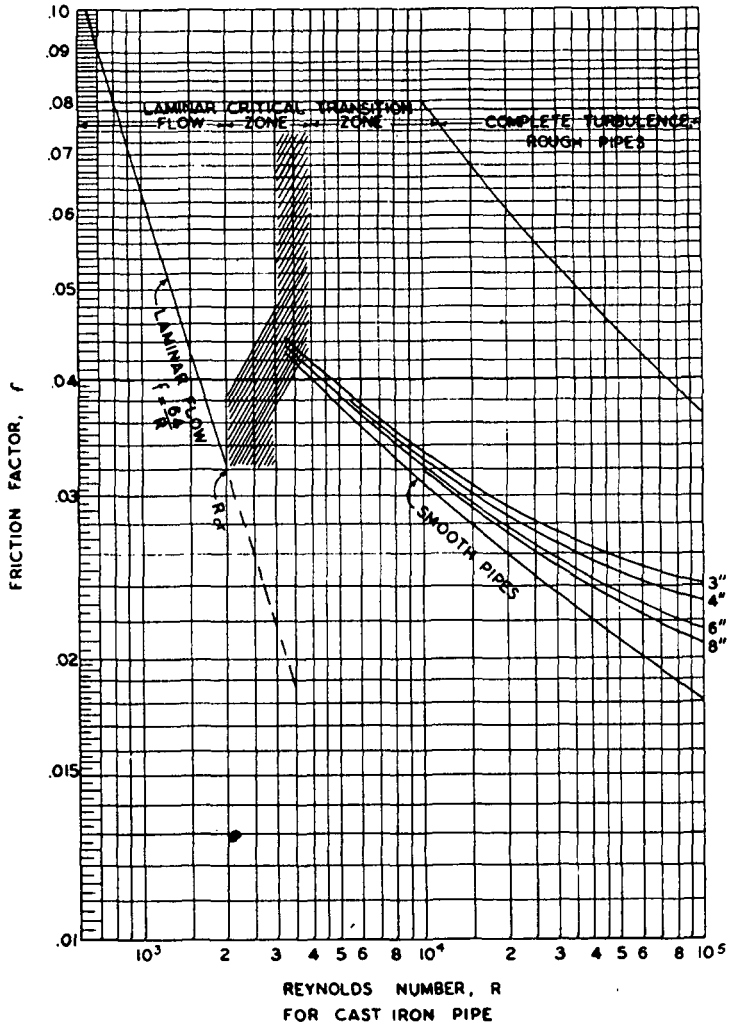


Figure A-4-6.4(1)