NFPA 11A

Standard for Medium- and High-Expansion Foam Systems

1999 Edition

This edition of NFPA 11A, *Standard for Medium- and High-Expansion Foam Systems*, was prepared by the Technical Committee on Foam and acted on by the National Fire Protection Association, Inc. at its Fall Meeting held November 16-18, 1998, in Atlanta, GA. It was issued by the Standards Council on January 15, 1999, with an effective date of February 4, 1999, and supersedes all previous editions.

This edition of NFPA 11A was approved as an American National Standard on February 4, 1999.

Origin and Development of NFPA 11A

Work on this standard commenced in 1964. Several drafts were prepared by the Medium- and High-Expansion Foam System Subcommittee and processed at committee meetings held in subsequent years. The subcommittee's draft was approved by the Foam Committee at its New York meeting in December of 1967. Thereafter, the material was published in the 1968 NFPA Technical Committee Reports for study and evaluation by the NFPA membership and others interested. It was approved as a tentative standard at the 1968 Annual Meeting.

During 1968 NFPA 11A was further revised and was submitted and adopted as a revised tentative standard at the 1969 Annual Meeting. After one more year as a tentative standard, it was officially adopted without revision at the 1970 Annual Meeting. Amendments were made in 1976 and 1981. Further amendments were made in 1982 and the title was changed to include medium-expansion foam. Amendments were made in 1987. Foam concentrate pump requirements were added to the 1994 edition.

The 1999 edition of the document is a reconfirmation. However, some editorial changes have been made to make the document more user-friendly.

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

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

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Standard for Medium- and High-Expansion Foam Systems

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

Information on referenced publications can be found in Chapter 5 and Appendix B.

Chapter 1 General

1-1 Scope.

This standard includes minimum requirements for the installation, design, operation, testing, and maintenance of medium- and high-expansion foam systems.

Only those skilled in the field are competent to design and install this equipment. It might be necessary for many of those charged with purchasing, inspecting, testing, approving, operating, and maintaining this equipment to consult with an experienced and competent fire protection engineer in order to effectively discharge their respective duties.

1-2 Purpose.

This standard is intended for the use of those responsible for purchasing, designing, installing, testing, inspecting, approving, listing, operating, or maintaining medium- and high-expansion foam systems, in order that such equipment will function as intended throughout its life.

1-3 History.

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

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

1-4* Description.

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

Optimum efficiency in any one type of hazard depends to some extent on the rate of application and the foam expansion and stability.

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

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

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

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

(a) Where generated in sufficient volume, medium- and high-expansion foam can prevent the free movement of air, which is necessary for continued combustion.

(b) Where forced into the heat of a fire, the water in the foam is converted to steam, thus reducing the oxygen concentration by dilution of the air.

(c) The conversion of the water to steam absorbs heat from the burning fuel. Any hot object exposed to the foam will continue the process of breaking the foam, converting the water to steam, and cooling.

(d) Because of its relatively low surface tension, solution from the foam that is not converted to steam will tend to penetrate Class A materials. However, deep-seated fires might require overhaul.

(e) Where accumulated in depth, medium- and high-expansion foam can provide an insulating barrier for protection of exposed materials or structures not involved in a fire and can thus prevent fire spread.

(f) For LNG fires, high-expansion foam will not normally extinguish a fire, but it will reduce the fire intensity by blocking radiation feedback to the fuel.

(g) Class A fires are controlled when the foam completely covers the fire and burning material. If the foam is sufficiently wet and is maintained long enough, the fire can be extinguished.

(h) Class B fires involving high-flash-point liquids can be extinguished when the surface is cooled below the flash point. Class B fires involving low-flash-point liquids can be extinguished when a foam blanket of sufficient depth is established over the liquid surface.

This standard is based on test data and design experience developed for the use of medium- and high-expansion foam. The intent of this standard is to indicate general rules applicable to any system. The limited field experience of approved systems makes it difficult to prepare specific recommendations covering the many potential uses. This standard outlines some of the factors that shall be given consideration in judging the acceptability of specific installations.

1-5 Definitions and Units.

1-5.1 Definitions.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

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

(a) *Protein-Foam Concentrates.* 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 ensure readiness for use under emergency conditions. They are diluted with water to form 3 percent to 6 percent solutions depending on the type. These concentrates are compatible with certain dry chemicals.

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

(c) *Synthetic-Foam Concentrates.* Synthetic-foam concentrates are based on foaming agents other than hydrolyzed proteins and include the following:

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

2. *Medium- and High-Expansion Foam Concentrates.* These concentrates, which are usually derived from hydrocarbon surfactants, are used in specially designed equipment to produce foams having foam-to-solution volume ratios of 20:1 to approximately 1000:1. This equipment can be air-aspirating or

blower-fan type.

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

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

(e) *Alcohol-Resistant Foam Concentrates.* These concentrates are used for fighting fires on water-soluble materials and other fuels destructive to regular, AFFF, or FFFP foams, as well as for fires involving hydrocarbons. There are three general types. One is based on water-soluble natural polymers, such as protein or fluoroprotein concentrates, and also contains alcohol-insoluble materials that precipitate as an insoluble barrier in the bubble structure.

The second type is based on synthetic concentrates and contains a gelling agent that surrounds the foam bubbles and forms a protective raft on the surface of water-soluble fuels; these foams can also have film-forming characteristics on hydrocarbon fuels.

The third type is based on both water-soluble natural polymers, such as fluoroprotein, and contains a gelling agent that protects the foam from water-soluble fuels. This foam can also have film-forming and fluoroprotein characteristics on hydrocarbon fuels.

Alcohol-resistant foam concentrates are generally used in concentrations of 3 to 10 percent solutions, depending on the nature of the hazard to be protected and the type of concentrate.

Foam Solution. A homogeneous mixture of water and foam concentrate in the proper proportion.

High-Expansion Foam.* An aggregation of bubbles resulting from the mechanical expansion of a foam solution by air or other gases with a foam-to-solution volume ratio ranging from 200:1 to approximately 1000:1.

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

Listed.* Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

Medium-Expansion Foam.* An aggregation of bubbles resulting from the mechanical expansion of a foam solution by air or other gases with a foam-to-solution volume ratio ranging from 20:1 to 200:1.

Shall. Indicates a mandatory requirement.

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

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law.Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

1-5.2 Units.

1-5.2.1

Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The liter unit, which is not part of but is recognized by SI, is commonly used in international fire protection. These units are listed in Table 1-5.2.1 with conversion factors.

Table 1-5.2.1 Metric Units

Name of Unit	Unit Symbol	Conversion Factor
liter	L	1 gal = 2.785 L
liter per minute per square meter	$(L/min)/m^2$	1 gpm/ft = $(40.746\ L/min)/m^2$
cubic decimeter	dm^3	1 gal = $3.785\ dm^3$
pascal	Pa	1 psi = 6894.757 Pa

For additional conversions and information see ANSI SI 10, *Standard for Use of the International System of Units (SI): the Modern Metric System.*

1-5.2.2

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 can be approximate.

1-5.2.3

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.

1-6 General Information and Requirements.

The information and requirements in Chapter 1 are generally common to all medium- and high-expansion foam systems.

1-6.1 Mechanisms of Extinguishment.

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

1-6.2 Use and Limitations.

1-6.2.1

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

1-6.2.2*

Some important types of hazards that medium- and high-expansion foam systems can satisfactorily protect include the following:

(a) Ordinary combustibles

(b) Flammable and combustible liquids

(c) Combinations of (a) and (b)

(d) Liquefied natural gas (high-expansion foam only)

1-6.2.3

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

1-6.2.4

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

1-6.2.5

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

(a) Chemicals, such as cellulose nitrate, that release sufficient oxygen or other oxidizing agents to sustain combustion

(b) Energized unenclosed electrical equipment *(see 1-7.2.2)*

(c) Water-reactive metals such as sodium, potassium, and NaK (sodium-potassium alloys)

(d) Hazardous water-reactive materials, such as triethyl-aluminum and phosphorous pentoxide

(e) Liquefied flammable gas

1-6.3 Types of Systems.

The types of systems recognized in this standard include the following:

(a) Total flooding systems

(b) Local application systems

(c) Portable foam-generating devices

1-6.4 Systems Protecting One or More Hazards.

1-6.4.1

Systems shall be permitted to be used to protect one or more hazards or groups of hazards by means of the same supply of foam concentrate and water except as provided in 1-6.4.2.

1-6.4.2

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

1-7 Personnel Safety.

1-7.1 Hazards to Personnel.

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

1-7.1.1

Where possible, the location of foam discharge points relative to building exits shall be arranged to facilitate evacuation of personnel. Additional exits and other measures might be necessary to ensure safe evacuation of personnel.

1-7.1.2

To reenter a foam-filled building, a coarse water spray shall be permitted to be used to cut a path in the foam. Personnel shall not enter the foam. The foam is opaque, making it impossible to see when one is submerged in it. It is dangerous to enter a building in which there was a fire if one cannot see.

1-7.2 Caution.

1-7.2.1

A canister-type gas mask shall not be worn in the foam. The chemicals of the canister can react with the water of the foam and cause suffocation. If emergency reentry is essential, self-contained breathing apparatus shall be used in conjunction with a life line.

1-7.2.2

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

1-7.3* Electrical Clearances.

All system components shall be located to maintain minimum clearances from live parts as shown in Table 1-7.3.

The clearances given are for altitudes of 3300 ft (1000 m) or less. At altitudes in excess of 3300 ft (1000 m), the clearance shall be increased at the rate of 1 percent for each 330 ft (100 m) increase in altitude above 3300 ft (1000 m).

The clearances are based on minimum general practices related to design basic insulation level (BIL) values. To coordinate the required clearance with the electrical design, the design BIL of the equipment being protected shall be used as a basis, although this is not material at nominal line voltages of 161 kV or less.

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

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

Possible design variations in the clearance required at higher voltages are evident in Table 1-7.3, where a range of voltages is indicated opposite the various BIL test values in the high-voltage portion of the table. However, the clearance between uninsulated energized parts of the electrical system equipment and any portion of the medium- or high-expansion foam system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

Table 1-7.3 Clearance from Medium- and High-Expansion Foam Equipment to Live Uninsulated Electrical Components

Nominal LineVoltage (kV)	Nominal Voltageto Ground (kV)	Design BIL[1] (kV)	Minimum (in.
To 15	To 9	110	7
23	13	150	10
34.5	20	200	13
46	27	250	17
69	40	350	25
115	66	550	37
138	80	650	44
161	93	750	52
196-230	114-132	900	63

Nominal LineVoltage (kV)	Nominal Voltageto Ground (kV)	Design BIL[1] (kV)	Minimum (in.
		1050	76
		1175	87
		1300	98
287-380	166-220	1425	109
		1550	120
500	290	1675	131
		1800	142
		1925	153
500-700	290-400	2100	168
		2300	184

[1]Basic insulation level (BIL) values are expressed as kilovolts (kV), the number being the crest value of the full the electrical equipment is designed to withstand.

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

1-8 Specifications, Plans, and Approval.

1-8.1 Purchasing Specifications.

Specifications for medium- and high-expansion foam systems shall be drawn up with care under the supervision of a competent engineer and with the advice of the authority having jurisdiction. To ensure a satisfactory system, the items listed in 1-8.1.1 through 1-8.1.3 shall be in the specifications.

1-8.1.1

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

1-8.1.2

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

1-8.1.3

The specifications shall include the specific tests that are 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, as determined by the authority having jurisdiction.

1-8.2.1

These plans shall be drawn to an indicated scale or be suitably dimensioned and shall be made so that they can be reproduced easily.

1-8.2.2*

These plans shall contain sufficient detail on the hazard to enable the authority having jurisdiction to evaluate the effectiveness of the system. The details on the hazard shall include the specific materials involved, the location and arrangement, and the immediate exposure to the hazard. The details on the system shall include information and calculations on the required amount of foam concentrate; water requirements; hydraulic calculations on the size, length, and arrangement of connected piping and hose; and the size and location of foam generators sufficient to determine the adequacy of the quantity, flow rate, and distribution of the medium- and high-expansion foam generated. Detailed information shall be submitted pertaining to the location and function of detection devices, operating devices, auxiliary equipment including standby power, and electrical circuitry, if used. Sufficient information shall be indicated to properly identify the apparatus and devices used. Any special features shall be adequately explained.

1-8.3 Approval of Plans.

1-8.3.1

Where plans are required, they shall be submitted to the authority having jurisdiction for approval before work starts.

1-8.3.2

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.

1-8.4 Approval of Installations.

The completed system shall be tested by qualified personnel to meet the approval of the authority having jurisdiction. These tests shall be adequate to determine that the system has been properly installed and will function as intended. Only listed or approved equipment and devices shall be used in these systems.

1-8.4.1

Such tests shall include a discharge of foam if possible. This foam shall be checked for desired quality. If actual discharge is not permitted, the supplier or installer shall check airflow and liquid flow in a manner satisfactory to the authority having jurisdiction.

1-8.4.2*

All piping connecting to each foam generator shall be subjected to a 2-hour hydrostatic test pressure at 200 psi (1379 kPa), or 50 psi (345 kPa) in excess of the maximum pressure anticipated, whichever is greater.

1-8.4.3

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

1-8.4.4

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

1-8.4.5

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

1-9 Operation and Control of Systems.

1-9.1 Methods of Actuation.

Systems shall be classified as manual or automatic in accordance with the method of actuation. An automatic system shall be actuated by automatic detection equipment. Such systems also shall have means for manual actuation.

1-9.2 Detection of Fires.

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

1-9.2.1

Automatic detection shall be used for fixed systems.

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

1-9.2.2*

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

1-9.2.3*

An adequate and reliable source of energy shall be used in detection systems. The power supply for electrical detection systems shall be independent of the supply for the protected area. Otherwise, an emergency, battery-powered supply with automatic switchover shall be provided if the primary supply fails.

1-9.3 Supervision.

Supervision of automatic detection and actuation equipment shall be provided and arranged so that there will be an immediate indication of failure, preferably at a constantly attended location.

1-9.4 Alarms.

Audible alarms shall be installed to indicate the operation of the system, to alert personnel, and to indicate failure of any supervised device or equipment. Such devices shall be of such a type and shall be provided in such numbers and at such locations as are necessary to accomplish satisfactorily their purpose, subject to approval of the authority having jurisdiction.

1-9.4.1

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

1-9.4.2

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

1-9.4.3

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

1-9.5* Operating Devices.

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

1-9.5.1

Operation shall be controlled by listed or approved mechanical, electrical, hydraulic, or pneumatic means. An adequate and reliable source of energy shall be used. The electrical power supply for an electrically operated medium- or high-expansion foam system shall be as reliable as a fire pump circuit in accordance with NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*.

1-9.5.2

All operating devices shall be suitable for the service they will encounter and shall not be readily rendered inoperative or susceptible to accidental operation. Provision shall be made to protect piping that is normally filled with liquid from freezing.

1-9.5.3

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

1-9.5.4

Manual controls for actuation and shutdown shall be conveniently located and easily accessible at all times, including the time of fire and system operation. Remote control stations for manual actuation might be required where the area is large, egress difficult, or where required by the authority having jurisdiction. Manual controls for actuation shall operate the system to the same extent as the automatic control.

1-9.5.5

All automatically operated equipment controlling the generation and distribution of foam shall be provided with approved independent means for emergency manual operation. If the means for manual actuation of the system required in 1-9.1 provide approved positive operation independent of the automatic actuation, it shall be permitted to be used as the emergency means. The emergency means, preferably mechanical, shall be easily accessible and located close to the equipment controlled. If possible, the system shall be designed so that complete emergency actuation can be accomplished from one location.

1-9.5.6

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

1-9.5.7

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

1-10 Water, Foam Concentrate, and Air Supply.

1-10.1 Water Quantity.

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

1-10.2 Water Quality.

Consideration shall be given to the suitability of the water for production of medium- and high-expansion foam. The use of salt water or hard water or the presence of corrosion inhibitors, antifreeze agents, marine growths, oil, or other contaminants can result in reduction of foam volume or stability. The manufacturer of the foam concentrate shall be consulted.

1-10.3 Water Storage.

Water supply shall be protected against freezing.

1-10.4 Foam Concentrate Quantity.

The amount of foam concentrate in the system shall be at least sufficient for the largest single hazard protected or a group of hazards that are to be protected simultaneously. *(See*

2-3.6.1 and 3-3.2.)

1-10.5* Foam Concentrate Quality.

The foam concentrate used in the system shall be that listed for use with the equipment or a foam concentrate of equivalent quality acceptable to the authority having jurisdiction. The performance of the system shall be dependent on the composition of the foam concentrate as well as other factors. The quality of the concentrate for proper performance under the installation requirements of this standard shall be determined by suitable tests. *[See A-1-10.5(b).]*

1-10.6 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 shall be permitted to be in separate tanks or compartments, in drums or cans on the premises, or available from an approved outside source within 24 hours.

1-10.7 Foam Concentrate Storage.

In-service and reserve supplies of foam concentrate shall be stored where the temperature is maintained between 35°F (2°C) and 100°F (38°C) or within such other temperature range for which the concentrate has been listed. The reserve supply containers shall be kept closed tightly in a clean, dry area to prevent contamination or deterioration.

1-10.8* Foam Concentrate Storage Tank.

The tank shall be of corrosion-resisting materials and construction compatible with the foam concentrate. Consideration shall be given to design of the storage tank to minimize evaporation of concentrate. The foam equipment manufacturer shall be consulted.

1-10.9 Air Supply.

1-10.9.1

Air from outside the hazard area shall be used for foam generation unless data is provided to show that air from inside the hazard can be successfully employed. The data shall be specific for the products of combustion to be encountered and shall provide factors for increasing foam discharge rates over those given in 2-3.5 if test fire indicates that need.

1-10.9.2

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

1-11 Foam-Generating Apparatus Location.

1-11.1 Accessibility for Inspection and Maintenance.

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

1-11.2* Protection Against Exposure.

Foam-generating equipment shall be located as close as possible to the hazard(s) it protects, but not where it will be unduly exposed to a fire or explosion. Foam generators installed inside the hazard area shall be constructed to resist or be protected against fire exposure. Such protection shall be permitted to be in the form of insulation, fire-retardant paint, water spray or sprinklers, and so forth. In certain applications, additional generators shall be permitted to be substituted for fire exposure protection with the approval of the authority having jurisdiction.

1-12 Distribution Systems.

1-12.1 Piping and Fittings.

The piping and fittings in continuous contact with foam concentrate shall be of corrosion-resisting materials compatible with the foam concentrate used. Galvanizing is not compatible with some foam concentrates. The remainder of the piping and fittings shall be standard weight (Schedule 40) black or galvanized steel pipe and standard weight black or galvanized steel, ductile, or malleable iron fittings. Consideration shall be given to possible galvanic effects when dissimilar metals are joined, especially in piping that carries foam concentrate.

1-12.2 Arrangement and Installation of Piping and Fittings.

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

1-12.2.1

All piping systems shall be designed using hydraulic calculations to ensure the desired rate of flow at the foam generators. Care shall be taken to avoid possible restrictions due to foreign matter, faulty fabrication, and improper installation.

1-12.2.2

A listed strainer suitable for use with the proportioner and foam generator shall be provided in the water line upstream of the water valve. Supplemental strainers shall be permitted to be used as recommended by the foam equipment manufacturer.

1-12.3* Foam Concentrate Pumps.

1-12.3.1

The design and materials of construction for foam concentrate pumps shall be suitable for use with the type of foam concentrate used in the system. Special attention shall be paid to the type of seal or packing used.

1-12-3.1.1

Where pumps utilizing cast or ductile iron components are used, the pumps shall be left flooded with concentrate to minimize corrosion, foaming, or sticking.

1-12.3.2

Foam concentrate pumps shall have adequate capacities to meet the maximum system demand. To ensure positive injection of concentrates, the discharge pressure ratings of pumps at the design discharge capacity shall be in excess of the maximum water pressure available under any condition at the point of concentration injection.

1-12.4 Valves.

1-12.4.1

All valves shall be suitable for the intended use, particularly in regard to flow capacity and operation. Valves shall be of a listed type or shall be deemed suitable for such use as a part of the system.

1-12.4.2

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

1-12.5 Ducts.

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

1-12.5.1

Duct closures such as selector valves, gates, or doors shall be of the quick-opening type, so as to allow free passage of the foam. When duct closures are located where they might be subjected to fire or heat exposure, either inside or outside the area to be protected, special care shall be taken to ensure positive operation.

1-12.5.2

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

1-13 Maintenance and Instructions.

1-13.1* Inspection and Tests.

At least annually, all medium- and high-expansion foam systems shall be thoroughly inspected and checked for proper operation by a competent engineer or inspector. This inspection shall include determination of any changes in physical properties of the foam concentrate that indicate any deterioration in quality.

1-13.1.1

The goal of this inspection and testing shall be to ensure that the system is in full operating condition and to indicate the probable continuance of that condition until the next inspection.

1-13.1.2

Suitable discharge tests shall be made where any inspection indicates their advisability.

1-13.1.3

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

1-13.1.4*

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

1-13.1.5

Strainers shall be inspected and cleaned after each use and test.

1-13.2 Maintenance.

1-13.2.1

Medium- and high-expansion foam systems shall be maintained in full operating condition at all times. Use, impairment, and restoration of this protection shall be reported promptly to the authority having jurisdiction.

1-13.2.2

Any troubles or impairments shall be corrected at once by competent personnel.

1-13.3 Instructions.

All persons who might 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.

1-13.3.1

Training programs approved by the authority having jurisdiction shall be established.

1-13.3.2

Operating instructions shall be posted at control stations.

Chapter 2 Total Flooding Systems

2-1 General Information.

2-1.1 Description.

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

2-1.2 Uses.

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

2-1.2.1*

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

2-1.2.2

Fires that can be controlled or extinguished by total flooding methods are divided into the following three categories:

- (a) Surface fires involving flammable or combustible liquids and solids
- (b) Deep-seated fires involving solids subject to smoldering
- (c) Three-dimensioned fires in some flammable liquids

2-1.3 General Requirements.

Total flooding systems shall be designed, installed, tested, and maintained in accordance with the applicable requirements of Chapters 1 and 2. Only listed or approved equipment and devices shall be used in these systems.

2-2 Enclosure Specifications.

2-2.1 Leakage and Ventilation.

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

2-2.1.1

Openings below design filling depth, such as doorways and windows, shall be arranged to close automatically before, or simultaneously with, the start of the foam discharge, with due consideration for evacuation of personnel. They shall be designed to maintain closure during a fire and be capable of withstanding pressures of foam and sprinkler water discharge. If any unclosable openings exist, the system shall be designed to compensate for the probable loss of foam and shall be tested to ensure proper performance.

2-2.1.2

Where outside air is used for foam generation, high-level venting shall be provided for air that is displaced by the foam. If possible, venting velocity shall not exceed 1000 ft/min (305 m/min) in free air. The required venting shall consist of suitable openings, either normally open or normally closed and arranged to open automatically when the system operates. Where design criteria demand exhaust fans, they shall be approved for high-temperature operation and installed with due consideration for protection of switches, wiring, and other electrical devices to ensure equal reliability of exhaust fan performance as well as for the foam generators. Where forced air ventilating systems interfere with the proper buildup of foam, they shall be shut down or closed off automatically.

2-3 Foam Requirements.

2-3.1 General.

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

2-3.2 Foam Depth.

2-3.2.1 High-Expansion Foam.

The minimum total depth of foam shall be not less than 1.1 times the height of the highest hazard but in no case less than 2 ft (0.6 m) over this hazard. For flammable or combustible liquids, the required depth over the hazard shall be permitted to be considerably greater and shall be determined by tests.

2-3.2.2 Medium-Expansion Foam.

Required depth over the hazard will vary with expansion. Depth shall be determined by tests. *(See A-1-10.5 for guidance.)*

2-3.3 Submergence Volume for High-Expansion Foams.

Submergence volume is defined as the depth as specified in 2-3.2.1 multiplied by the floor area of the space to be protected, or, in the case of unsprinklered rooms of internal combustible construction or finish, the entire volume including concealed spaces. The volume occupied by vessels, machinery, or other permanently located equipment shall be permitted to be deducted when determining the submergence volume. The volume occupied by stored material shall not be deducted when determining the submergence volume unless approved by the authority having jurisdiction.

2-3.4* Submergence Time for High-Expansion Foams.

Recommended times to achieve submergence volume for various types of hazards and building construction are shown in Table 2-3.4. Shorter submergence times might be required depending on the factors included in 2-3.5.

Table 2-3.4 Maximum Submergence Time for High-Expansion Foam Measured from Start of Foam Discharge[a] (Minutes)

	Light or UnprotectedSteel Construction		Heavy or Protectedor Fi
Hazard	**Sprinklered**	**Not Sprinklered**	**Sprinklered**
Flammable liquids [flash points below 100°F (38°C)] having a vapor pressure not exceeding 40 psia (276 kPa)[a]	3	2	5
Combustible liquids [flash points of 100°F (38°C) and above][b]	4	3	5
Low-density combustibles (i.e., foam rubber, foam plastics, rolled tissue, or crepe paper)	4	3[c]	6
High-density combustibles (i.e., rolled paper kraft or coated banded)	7	5[c]	8
High density combustibles (i.e., rolled paper kraft or coated unbanded)	5	4[c]	6
Rubber tires	7	5[c,d]	8
Combustibles in cartons, bags, or fiber drums	7	5[c]	8

[a] This submergence time is based on a maximum of 30 seconds delay between fire detection and start of foam di excess of 30 seconds shall be deducted from the submergence times in Table 2-3.4.

[b] Polar solvents are not included in this table. Flammable liquids having boiling points less than 100°F (38°C) n application rates. See NFPA 30, *Flammable and Combustible Liquids Code*. Where use of high-expansion foam these materials, the foam equipment supplier shall substantiate suitability for the intended use.

[c] These submergence times might not be directly applicable to high-piled storage above 15 ft (4.6 m) or where f combustible contents is very rapid.

[d] High-expansion foam protection without sprinkler protection is not recognized within the scope of NFPA 231I *of Rubber Tires*.

2-3.5* Rate of Discharge.

2-3.5.1 Medium-Expansion Foam.

The rate of discharge for medium-expansion foam shall be determined by tests.

2-3.5.2 High-Expansion Foam.

The rate of foam discharge necessary for extinguishment or sufficient control to permit overhaul depends on the strength of sprinkler protection, the nature and configuration of the hazard, the vulnerability of the structure and contents to fire, and the loss potential to life, property, and production. The rate also depends on foam properties, such as expansion ratio, water retention, effect of water contaminants, and temperature effects on water retention. The foam discharge rate shall be sufficient to satisfy the foam depth requirements and submergence times of Table 2-3.4, with compensation for normal foam shrinkage, foam leakage, and breakdown effects of sprinkler discharge.

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

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

where:

R = rate of discharge in ft^3/min (m^3/min)

V = submergence volume in ft^3 (m^3)

T = submergence time in minutes

R_S = rate of foam breakdown by sprinklers in ft^3/min (m^3/min)

C_N = compensation for normal foam shrinkage

C_L = compensation for leakage

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

$$R_S = S \times Q$$

where:

S = foam breakdown in ft^3/min · gpm of sprinkler discharge. S shall be 10 ft^3/min · gpm (0.0748 m^3/min · L/min)

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

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

(d) * The factor (C_L) for compensation for loss of foam due to leakage around doors and windows and through unclosable openings shall be determined by the design engineer after proper evaluation of the structure. This factor cannot be less than 1.0 even for a structure completely tight below the design filling depth. This factor could be as high as 1.2 for a building with all openings normally closed, depending on foam expansion ratio, sprinkler operation, and foam depth.

2-3.6 Quantity.

2-3.6.1

Sufficient high-expansion foam concentrate and water shall be provided to permit continuous operation of the entire system for 25 minutes or to generate four times the submergence volume, whichever is less, but in no case less than enough for 15 minutes of full operation. *(See 1-10.4.)* The quantity for medium-expansion foam shall be determined by suitable tests developed by an independent testing laboratory.

2-3.6.2

Reserve supplies shall be provided in accordance with 1-10.7.

2-4* Maintenance of Submergence Volume for High-Expansion Foam.

To ensure adequate control or extinguishment, the submergence volume shall be maintained for at least 60 minutes for unsprinklered locations and 30 minutes for sprinklered locations. Where only flammable or combustible liquids are involved, this period shall be permitted to be reduced.

2-4.1 Method.

2-4.1.1

The submergence volume can be maintained by continuous or intermittent operation of any or all of the generators provided.

2-4.1.2

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

2-5* Overhaul.

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

2-6 Distribution.

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

Chapter 3 Local Application Systems

3-1 General Information.

3-1.1 Description.

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

3-1.2 Uses.

Local application systems shall be permitted to be used for the extinguishment or control of fires in flammable or combustible liquids, liquefied natural gas (LNG), and ordinary Class A combustibles where the hazard is not totally enclosed. These systems are best adapted to the protection of essentially flat surfaces such as confined spills, open tanks, drainboards, curbed areas, pits, trenches, and so forth. For multiple-level or three-dimensional fire hazards where total building flooding is impractical, the individual hazard shall be provided with suitable containment facilities acceptable to the authority having jurisdiction.

3-1.3 General Requirements.

Local application systems shall be designed, installed, tested, and maintained in accordance with the applicable requirements in Chapters 1, 2, and 3. Only listed or approved equipment, devices, and agents shall be used in these systems.

3-2 Hazard Specifications.

3-2.1 Extent of Hazard.

The hazard shall include all areas to or from which fire can spread.

3-2.2* Location of Hazard.

Local application medium- and high-expansion foam systems can be used to protect hazards located indoors, under partial shelter, or completely outdoors. Provisions shall be made to compensate for winds and other effects of weather.

3-3 Foam Requirements for Flammable and Combustible Liquids and Solids.

3-3.1 General.

Sufficient foam shall be discharged at a rate to cover the hazard to a depth of at least 2 ft (0.6 m) within 2 minutes. *(See 2-3.2 and 2-3.5.)*

3-3.2 Quantity.

3-3.2.1

Sufficient foam concentrate and water shall be provided to permit continuous operation of the entire system for at least 12 minutes. *(See 1-10.4.)*

3-3.2.2

Reserve supplies shall be provided in accordance with 1-10.7.

3-3.3 Arrangement.

Discharge outlets shall be arranged to ensure that foam is delivered over all areas that constitute the hazard. Where parts of the hazard are elevated or raised up from the ground or floor line, the arrangement of the system shall be such that foam will be delivered to, and retained on, such parts in sufficient depth to ensure prompt and final extinguishment.

3-4* Foam Applications for Liquefied Natural Gas (LNG).

3-4.1* General.

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

3-4.2* System Design Considerations.

The determination of the high-expansion foam system design shall depend on an analysis specific to the individual site. Since time to initiate actuation is a critical factor in LNG fire control, the analysis shall consider effects of heat exposure on adjacent plant equipment. In many cases, automatic alarms and actuation shall be required for fixed systems.

3-4.3* Application Rate.

As established by tests *[see A-1-10.5(d)]*, the application rate shall be such that a positive and progressive reduction in radiation is attained within the time limitations established in the analysis. The application rates determined by the test in A-1-10.5(d) shall be increased by the necessary factor to account for the initial vaporization rate and the configuration of the hazard. After steady-state control conditions have been reached, the application rates established in the test for maintenance of fire control shall be used to maintain control.

3-4.4 Quantity.

The initial quantity of foam concentrate shall permit a continuous application at the initial design rate sufficient for fire control to reach steady-state conditions. Additional foam concentrate supplies shall be on hand to provide control maintenance for the calculated fire duration.

3-4.5* Foam System Arrangement.

The foam system shall have foam outlets arranged to supply foam to cover the design fire area within the specified time.

Chapter 4 Portable Foam-Generating Devices

4-1 General Information.

4-1.1 Description.

Portable foam-generating devices consist of a foam generator, manually operable and transportable, connected by means of hose, or piping and hose, to a supply of water and foam concentrate. The proportioning equipment can be integral to or separate from the foam generator. A separate foam concentrate supply can be provided for each unit, or solution can be piped from central proportioning equipment.

4-1.2 General Requirements.

Portable foam-generating devices and associated equipment shall be used and maintained in accordance with the applicable requirements in Chapters 1, 2, 3, and 4. Only listed or approved equipment and devices shall be used.

4-2 Hazard Specifications.

Portable foam-generating devices shall be permitted to be used to combat fires in all hazards covered in Chapters 2 and 3.

4-3 Location and Spacing.

Portable foam-generating devices that are preconnected to a water or solution supply shall be placed where they are easily accessible and shall have enough hose to reach the most distant hazard they are expected to protect. Foam concentrate shall be available for immediate use. These devices shall be located such that they are not exposed to the hazard. Those not preconnected to a water or solution supply and their associated equipment shall be located and arranged for immediate transport to all designated hazards.

4-4 Foam Requirements.

4-4.1 Rate and Duration of Discharge.

The rate and duration of discharge, and consequently the quantity of foam concentrate and water, shall be determined by the type and potential size of hazard. To the extent that the specific hazards can be identified, the applicable requirements of Chapters 2 or 3 shall apply.

4-4.2 Simultaneous Use of Portable Foam-Generating Devices.

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

4-5 Equipment Specifications.

4-5.1 Hose.

Hose used to connect the generator to the water or solution supplies shall be listed lined hose. Unlined fabric hose shall not be used. The hose size and length shall be selected with consideration to the hydraulics of the entire system. Such hose shall be stored in an arrangement that will permit immediate use and shall be protected against the weather.

4-5.2 Electric Power Supply and Connections.

Power supply and connections needed for operation of the generator shall be adequate to transmit the required power and shall be selected with consideration given to the intended use. All power cables shall be sufficiently rugged to withstand abuse in service, shall be impervious to water, and shall contain a ground wire. Electrical connectors shall be waterproof.

4-6 Training.

Successful extinguishment of fire with portable foam-generating devices is dependent on the individual ability and technique of the operator. All personnel likely to use this equipment shall be properly trained in its operation and in the necessary fire-fighting techniques.

Chapter 5 Referenced Publications

5-1

The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix B.

5-1.1 NFPA Publications.

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

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 18, *Standard on Wetting Agents*, 1995 edition.

NFPA 20, *Standard for the Installation of Centrifugal Fire Pumps*, 1996 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 1996 edition.

NFPA 70, *National Electrical Code®*, 1999 edition.

NFPA 231D, *Standard for Storage of Rubber Tires*, 1998 edition.

5-1.2 ANSI Publication.

American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.

ANSI SI 10, *Standard for Use of the International System of Units (SI): the Modern Metric System*, 1997.

Appendix A Explanatory Material

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

A-1-4

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

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

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

A-1-5.1 Approved.

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

A-1-5.1 Authority Having Jurisdiction.

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, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-5.1 High-Expansion Foam.

See A-1-9.5.

A-1-5.1 Listed.

The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations 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.

A-1-5.1 Medium-Expansion Foam.

See A-1-9.5.

A-1-6.2.2

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

A-1-7.3

As used in this standard, "clearance" is the air distance between medium- or high-expansion foam equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential. Since medium- and high-expansion foams are conductive, these clearances do not prevent conduction through foam. *(See 1-7.2.2.)*

A-1-8.2.2

See Chapter 6 of NFPA 13, *Standard for the Installation of Sprinkler Systems*, for calculation procedures.

A-1-8.4.2

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

A-1-9.2.2

See NFPA 72, *National Fire Alarm Code®*.

A-1-9.2.3

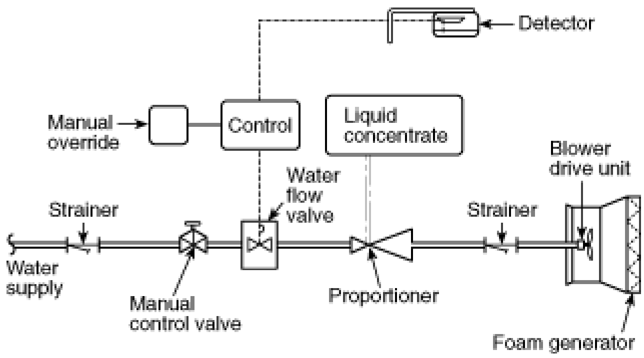
See applicable provisions of NFPA 72, *National Fire Alarm Code,* for power supply requirements.

A-1-9.5

A block diagram of a typical automatic medium- or high-expansion foam system is shown in Figure A-1-9.5.

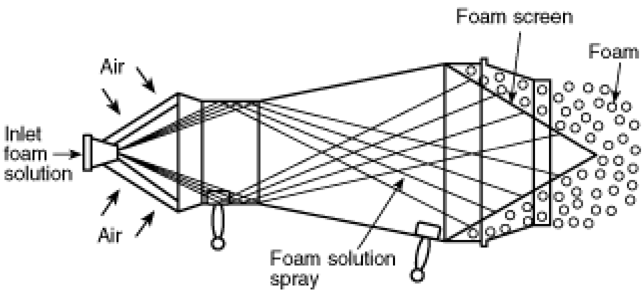
At the present time, foam generators for medium- and high-expansion foam are of two types, depending on the means for introducing air — by aspirator or blower. In either case, the properly proportioned foam solution is made to impinge at appropriate velocity on a screen or porous or perforated membrane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

Figure A-1-9.5 Block diagram of automatic medium- or high-expansion foam system.



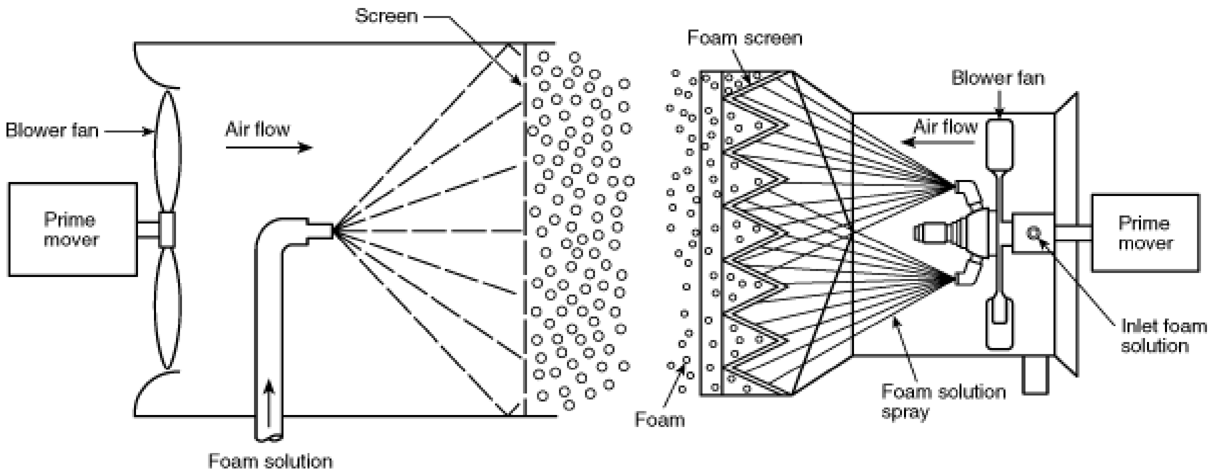
(a) *Foam Generators — Aspirator Type.* Foam generators can be fixed or portable. Jet streams of foam solution aspirate sufficient amounts of air that is then entrained on the screens to produce foam. *[See Figure A-1-9.5(a).]* These generators usually produce foam with expansion ratios of not more than 250:1.

Figure A-1-9.5(a) Aspirating-type foam generator.



(b) *Foam Generators — Blower Type.* Foam generators can be fixed or portable. The foam solution is discharged as a spray onto screens through which an airstream developed by a fan or blower is passing. The blower can be powered by electric motors, internal combustion engines, air, gas, or hydraulic motors or water motors. The water motors are usually powered by foam solution. *[See Figure A-1-9.5(b).]*

Figure A-1-9.5(b) Blower-type foam generators.



A-1-10.5

Foam Concentrate Quality.

(a) *Fire Performance Test for Class A Materials.* Suitable tests based on fire performance on Class A fires with a flammable liquid accelerant, performance on Class B fires, and performance on LNG fires are described in this appendix section. The purpose of this test is to provide a reproducible Class A fire situation where foam is required to move a substantial distance at a slow rate to work the fire. The time to move this distance and to fill to the top of the test combustibles is the *Foam Transit Time*. The effect of the transit time is to give age to the foam during the period of its slow movement from foam generator to fire.

The test should be conducted in an open-top pen or building of suitable construction and suitable dimensions. To prevent the velocity of foam movement from being too high, the width of the pen or building times 100 should give a figure not smaller than the capacity in cubic feet per minute of the foam generator used in the test. The height of the sides of the pen or building should be about 10 ft (3 m). If the fluidity of the foam permits, the height can be less. However, the foam should neither flow over the sides of the pen nor contact the ceiling of the building during the test. The foam generator should be set at one end of the pen or building, and the fire should be set 10 ft (3 m) from the opposite end. The distance between the foam generator and the fire should be as required to give the desired foam transit time. *[See Figure A-1-10.5(a).]*

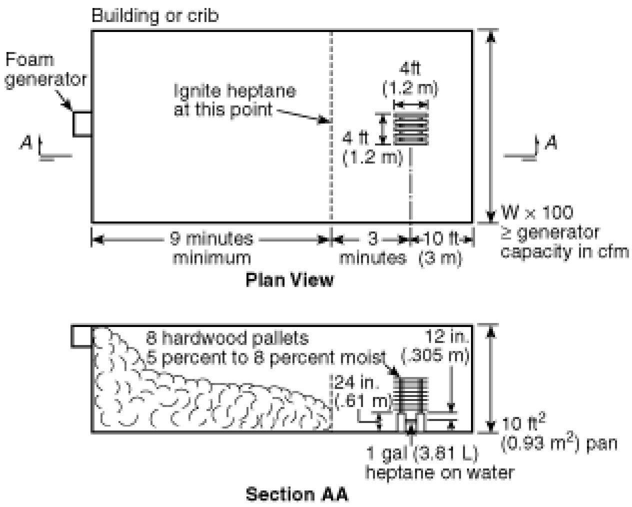
Foam should be produced by a generator in which the expansion ratio is approximately that produced by the generator proposed for installation.

The test fire should be made with a stack of eight standard 4 ft × 4 ft (1.22 m × 1.22 m) hardwood pallets dried to a moisture content between 5 and 8 percent, set on suitable noncombustible supports not more than 24 in. (610 mm) above the floor. Beneath the pallets should be a 10-ft^2 (0.93-m^2) pan containing 1 gal (3.8 L) of heptane or naphtha floating on water. The surface of the flammable liquid should be approximately 12 in. (305 mm) below the bottom boards of the bottom pallet.

The first test of each series should be a timed fill without a fire to determine the foam transit time. The location of the leading edge of the foam as it progresses across the floor of the pen or building should be timed at suitable intervals. Also, the time should be noted when the foam reaches the edge of the pan. This data will permit estimating, with reasonable accuracy, the location of the leading edge of the foam 3 minutes before the foam reaches the edge of the pan. Thereafter, during each fire test, the heptane should be ignited when the foam reaches that point corresponding to 3 minutes in advance of reaching the pan. In this manner the fire is given a reproducible 3-minute preburn. This fill test can be terminated when the foam has filled to the top of the wood pallets and the foam transit time has been determined.

The minimum foam transit time should be 12 minutes (150 percent of the maximum submergence time of 8 minutes, from Table 2-3.4). To be considered successful under the foam transit time condition, the foam should give adequate control of the test fire. The foam generator should be run for a maximum of 30 minutes. Adequate control should be interpreted as the absence of active burning within the test stack while the stack is covered with foam.

Figure A-1-10.5(a) Fire performance test.



(b) *Quality Control Test.* The laboratory scale expansion and drainage test described in the following list has been found suitable for quality control purposes. The air and solution temperatures are to be maintained between 60°F and 65°F (15.6°C and 18.3°C).

1. Mix foam solution.
2. Fill foam solution can with solution.
3. Weigh foam solution can and thread onto apparatus.
4. Apply 25 psi (172 kPa) air pressure to liquid.
5. Start blower and adjust damper to approximately $^1/_3$ opening. (The damper might have to be adjusted later in order for the desired expansion ratio to be obtained.)
6. Open solenoid. Adjust liquid pressure to 15 psi (103 kPa) using liquid metering valve. (Later readjustment might be necessary.)

7. As foam forms at screen, catch first droplets in beaker. Keep liquid in beaker to add to residue in foam can.

8. Allow drainage drum to fill with expanded foam. Start timer and shut off solenoid when drum is full.

9. Add liquid from step 7 to foam solution can and weigh again. Record total millileters used. (1 g is approximately 1 ml.)

10. Record liquid drainage in millileters at 1-minute intervals for 5 minutes, then at 10-minute intervals.

11. Plot time versus percent drained and record expansion ratio.

$$\text{Percent drained} = \frac{\text{Total ml drained to given time} \times 100}{\text{Total ml used}}$$

$$\text{Expansion ratio} = \frac{\text{Drum volume ml}}{\text{Total ml used}}$$

[See Figures A-1-10.5(b)(1) and A-1-10.5(b)(2).]

Figure A-1-10.5(b)(1) High-expansion foam quality test generator.

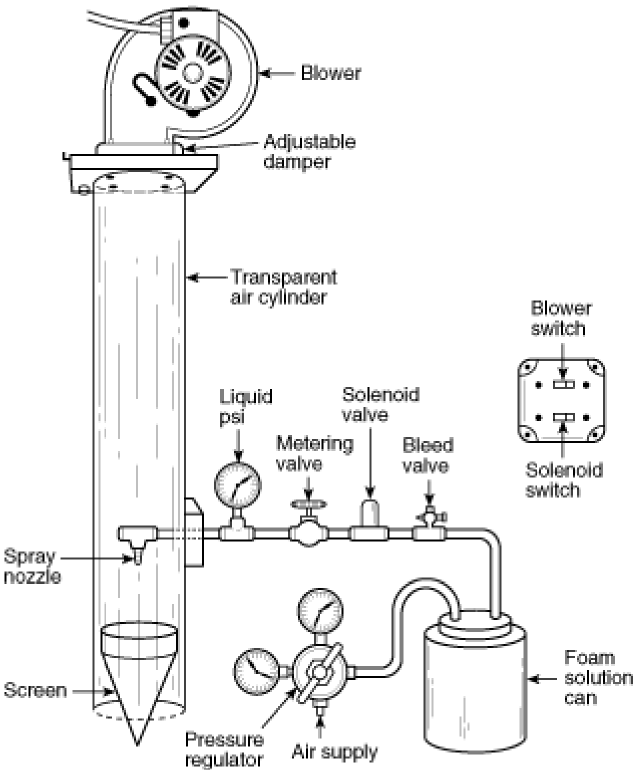
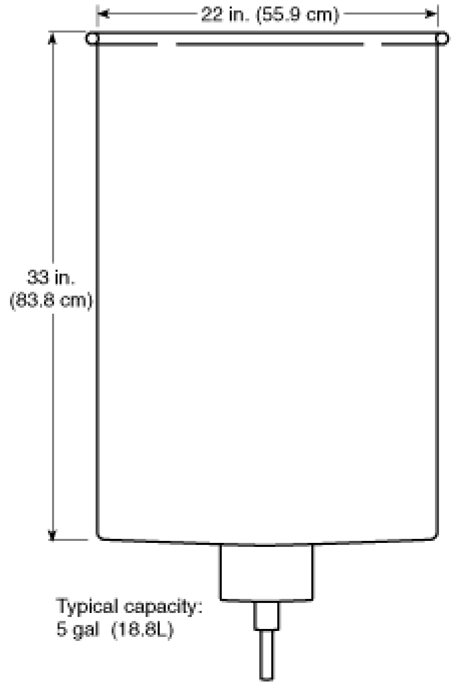


Figure A-1-10.5(b)(2) Typical drainage drum for high-expansion foam expansion and drainage test.



Note: Drum dimensions can vary ±5 percent from the typical values shown.

(c) *Fire Performance Test for Class B Materials.* The purpose of this test is to provide a reproducible Class B fire situation where foam is required to move a substantial distance at a slow rate toward the fire. The time to move this distance and to fill to the top of the test pan is the *Foam Transit Time*. The effect of the transit time is to give age to the foam during the period of its slow movement from foam generator to fire.

The test should be conducted in an open-top pen or building of suitable construction and suitable dimensions. To prevent the velocity of foam movement from being too high, the width of the pen or building times 100 gives a figure not smaller than the capacity in cubic feet per minute of the foam generator used in the test. The height of the sides of the pen or building should be 10 ft (3 m). If the fluidity of the foam permits, the height can be less. However, the foam must neither flow over the sides of the pen nor contact the ceiling of the building during the test. The foam generator should be set at one end of the pen or building, and the fire should be 10 ft (3 m) from the opposite end. The distance between the foam generator and the fire is as required to give the desired foam transit time. Foam should be produced by a generator in which the expansion ratio is approximately equal to that produced by the generator for installation.

Flammable liquid fire tests are conducted using a 50-ft^2 (4.6-m^2) steel pan, square in shape, and 12 in. (300 mm) in depth, filled with a 2-in. (50-mm) layer of N-heptane and a 4-in. (100-mm) layer of water to obtain a freeboard of 6 in. (150 mm). The test pan is located on the floor.

The fuel is ignited and foam discharge is started to allow the fuel to burn for approximately 1 minute before the foam reaches the top edge of the pan. Observations as to transit time and whether or not the fire is extinguished are made.

The minimum foam transit time is 7.5 minutes. To be considered successful under the foam transit time condition, the foam must extinguish the test fire. The foam generator can be run for a maximum of 15 minutes.

The results of these tests should be recorded in the format illustrated in Table A-1-10.5(c).

Table A-1-10.5(c) Foam Type Test Report

Test No.	Fire Type	Time Generator Started After Ignition		Time to Cover Pan		Inlet Pressure in psi	No Visible Flame		Fir
		Minutes	Seconds	Minutes	Seconds		Minutes	Seconds	Minut
—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—

(d) *Standard Evaluation Test of High-Expansion Foam Systems for LNG Fires.*

1. *Purpose.* The purpose of this standard test is to evaluate the effectiveness of high-expansion foam systems applied to LNG fires for fire control.

2. *Definitions.*

   a. *Fire control time* is the elapsed time from the beginning of foam application until the average radiation levels, $1^1/_2$ pool widths from the pool center measured in the crosswind direction, have reached 10 percent of the initial steady-state uncontrolled values.

   b. *Foam application rate* is the expanded foam flow rate in cubic feet per minute per square foot of LNG surface area.

3. *Test Equipment.*

   a. A test pit configured as shown in Figure A-1-10.5(d)

   b. Four wide-angle, water-cooled radiometers with continual recording instruments for each

   c. Weather instruments for measuring temperature and relative humidity and measuring and recording wind velocity and direction during the tests

   d. Stopwatches

   e. Calibrated equipment for measuring water and foam concentrate flows or foam solution flows if premixed

   f. A foam generator calibrated to determine its performance curve of water pressure, output, expansion ratio, and expanded foam drainage rate

4. *Test Procedure.*

   a. All test instrumentation must be checked or calibrated prior to conducting the tests.

   b. The foam solution rate, foam concentrate proportioning ratio or total solution flow rate if the solution is premixed, and foam generator inlet solution pressure as specified by the equipment manufacturer should be set and maintained throughout the test.

c. Radiometers should be positioned as shown in Figure A-1-10.5(d).

d. As shown in Figure A-1-10.5(d), a single foam generator should be centered along the upwind side of the pool. A single foam application rate must be established and cannot be changed after ignition. All foam generated should be applied to the test pit. The control time will commence at the time of first visible foam at the application point.

e. The water flow and foam concentrate flow, or the solution flow, if premixed, should be monitored and recorded to ensure proper proportioning and application rates.

f. At the start of the test, the wind should be not more than 9 knots (10 mph or 16 km/hr) with maximum gusts to 13 knots (15 mph or 24 km/hr). For optimum test conditions with minimum LNG vaporization, standing water should not be in the pit.

g. At least 5 gal/ft^2 (1.76 L/m^2) of LNG, with a storage temperature not warmer than -151°C (-240°F) and an analysis of at least 85 percent methane, should be discharged into the pit. The first ignition of the pit must occur within 30 minutes of the beginning of discharge.

h. After ignition there must be a preburn until the fire stabilizes as indicated by the radiometers, but not longer than 45 seconds.

i. Foam application should commence and the fire control time should be measured.

j. Once control is established, the application rates for maintenance of fire control should be determined by shutting off the foam and allowing the fire to build up to 25 percent of initial intensity, then reapplying the foam until radiation levels are reduced to 10 percent of the initial uncontrolled intensity. A minimum of three cycles should be repeated.

5. *Report.* Include the following data in the test report.

a. Date and time of tests

b. Location of tests

c. Testing agency

d. Model of equipment and materials tested

e. Temperature, relative humidity, wind speed and direction, water temperature and quality (potable or nonpotable and fresh or salt), and general weather conditions for each test

f. Initial LNG analysis before discharge into pit

g. Depth of LNG in pit

h. Foam generator performance data

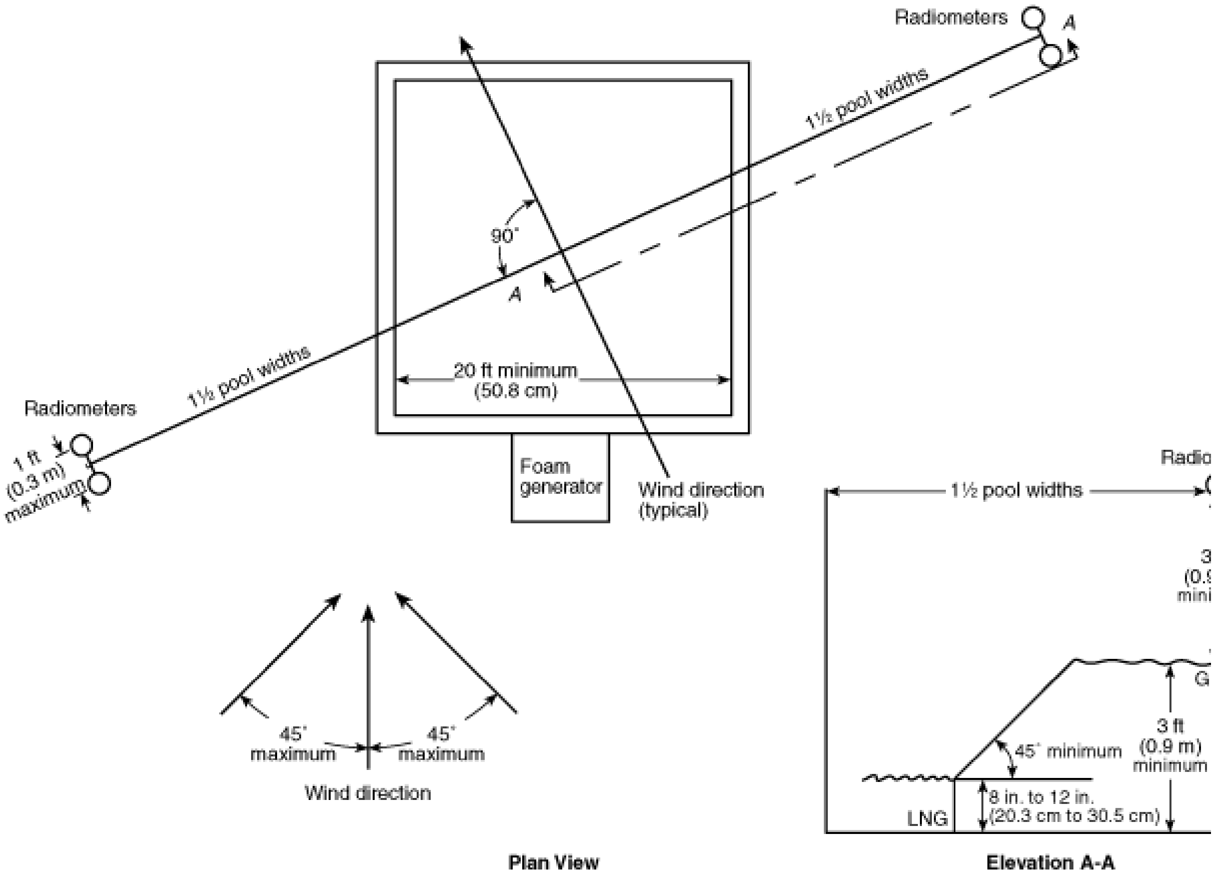
i. Data for all recording and measuring devices

j. Pit dimensions, orientation, and test setup

k. Application rates, expansion ratios, and supporting measurements

l. Curve showing time versus radiation levels, marked to show control times and beginning and end of foam application for each test

Figure A-1-10.5(d) High-expansion foam standard evaluation test pit.



A-1-10.8

Exposure of the foam concentrate to the atmosphere can cause evaporation of some or all components of the concentrate and, in some cases, can cause crusting of the agent. This condition is exaggerated when a tank with an open vent is located in an area where the temperature fluctuates.

For example, sunlight striking a tank during the day will cause the concentrate to expand and some concentrate vapors to escape. When the tank cools at night, fresh air will be drawn in to replace the lost vapors. Over a period of time, the amount and the composition of the concentrate can change. This loss can be minimized by designing the concentrate tank to include the following:

(a) An expansion dome that reduces the free surface of the concentrate to an area much smaller than the tank

(b) A pressure-vacuum valve that reduces the amount of escaping vapors and also reduces the amount of fresh air entering the tank

A-1-11.2

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

A-1-12.3

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

A-1-13.1

Regular service contracts with the manufacturer or installing company are recommended.

A-1-13.1.4

Weekly recorded inspections of medium- and high-expansion foam systems should be made. Items to be checked include the following, as applicable:

(a) *Foam Control Room, Including Foam Concentrate Supply System.*

1. Foam concentrate pumps, tanks, and lines checked for leaks or damage? Concentrate level in tanks normal?
2. Concentrate pumps operating properly?
3. All manually operated shutoff valves for the system properly positioned and locked?
4. Central panel lights operating properly?
5. All disconnects in the control panel in ON position?
6. Water supply pressure and flow rate normal?
7. Batteries fully charged? Liquid level normal?
8. Fire alarm and trouble alarms tested? Silence switches in normal position?
9. All supervised functions checked for proper operation?

(b) *Electric Foam Generators.* All disconnect switches in the ON position and locked?

(c) *Sprinkler Water Supply and Alarms.*

1. Water pressure on sprinkler risers normal?
2. Water flow alarms tested?
3. All manually operated shutoff valves locked open?

(d) *Protected Area.* All closures operating properly?

A-2-1.2.1

See NFPA 231C, *Standard for Rack Storage of Materials.*

A-2-3.4

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

A-2-3.5

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

A-2-3.5.2(a)

Sample Calculation of Total High-Expansion Foam Generator Capacity.

(a) *Calculation using U.S. units.*

Given:

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

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

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

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

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

Calculation:

Foam Depth

Depth = 25 × 1.1 = 27.5 ft

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

Submergence Volume

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

Submergence Time

T = 5 minutes (from Table 2-3.4)

Rate of Foam Breakdown by Sprinklers

S = 10 ft^3/min · gpm [from 2-3.5.2(b)]

Q = Number of heads × area/head × density

= 50 × (10 × 10) × 0.25 = 1250 gpm

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

Normal Foam Shrinkage

C_N = 1.15 [from 2-3.5.2(c)]

Leakage

C_L = 1.2 (assumption)

Total Generator Capacity

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

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

R = 169,000 ft^3/min

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

(b) *Calculation using SI units.*

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

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

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

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

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

Calculation:

Foam Depth

Depth = 7.6 × 1.1 = 8.4 m

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

Submergence Volume

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

Submergence Time

T = 5 minutes (from Table 2-3.4)

Rate of Foam Breakdown by Sprinklers

S = 0.0748 m^3/min · L/min [from 2-3.5.2(b)]

Q = Number of heads × area/head × density

= 50 × (3 × 3) × 10.2 = 4590 L/min

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

Normal Foam Shrinkage

C_N = 1.15 [from 2-3.5.2(c)]

Leakage

C_L = 1.2 (assumption)

Total Generator Capacity

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

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

$$R = 4787 \text{ m}^3/\text{min}$$

A-2-3.5.2(b)

Rate of Breakdown by Sprinklers.

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

A-2-3.5.2(d)

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

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

A-2-4

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

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

(a) All persons should be aware of the necessity for tight closure. Employees, brigade members, and the fire department should move rapidly to close any openings through which foam is being lost. Improvised closures can be made of practically any available material such as fine mesh screening, plastic, plywood, or cardboard.

(b) If the material involved is liable to sustain deep-seated fires, such as furniture, packaged material, fibers, and rolls of paper, particular care must be exercised in opening up the areas and removing the foam. Even where only surface fire is thought possible, as in flammable liquids, smoldering Class A material can cause reignition.

(c) A “soaking” period should elapse before foam is removed. This period can be as long as an hour and should be predetermined based on the fuel in the area.

A-2-5

The following points should be considered during overhaul operations.

(a) All foam and sprinkler systems that are shut off should have personnel standing by valves to turn them back on if this should become necessary.

(b) Foam supplies should be replenished if depleted.

(c) Hand hose lines should be charged and manned. Personal protective equipment should be donned. Self-contained breathing apparatus must be worn in the "ready" position so there will be no delay in putting it in service.

(d) Foam should be removed first from the fire area and should be coordinated with overhaul and salvage operations. The total loss will be kept to a minimum if thoughtless operations are avoided. Once the fire is under control, undue haste to extinguish the last ember can greatly increase the loss.

(e) Caution should be taken in entering previously foam-filled areas, particularly in structures with pits or openings in the floor.

(f) The area should be well ventilated, but openings through which foam might be lost should be kept to a minimum and manned for closing if this should become necessary.

(g) Consideration should be given to disposal of the foam to prevent any undue hazard to adjacent areas.

A-3-2.2

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

A-3-4

Special Provisions for Liquefied Natural Gas (LNG) Fire and Vapor Control.

(a) *Application Concepts for Fire Control.* Tests sponsored by the American Gas Association (AGA) have shown that the amount of radiation from a burning LNG spill can be reduced by as much as 95 percent with some high-expansion foams. This reduction is due in part to the foam barrier, which reduces vaporization by blocking heat feedback from the flames to the LNG. Foams having a low-expansion ratio contain a great deal of water at ambient temperature that tends to increase the vaporization rate when it drains into the LNG. In the AGA tests, control was established with expansion ratios greater than 250:1, although an expansion ratio of about 500:1 proved most effective. Different brands of foam show considerable variation in their ability to control LNG fires. A rapidly draining foam will increase the LNG vaporization rate and exaggerate the fire intensity. The drier foam remaining is less resistant to thermal effects and breaks down more readily. Other factors such as bubble size, fluidity, and linear burn rate can affect fire control. Therefore, test results on LNG fires, including the test described in A-1-10.5(d), should be reviewed before selecting a foam for LNG fire control.

(b) *Downwind Vapor Hazard Control.* When first evolved from a spill, unignited LNG vapors are heavier than air. As these vapors are heated by sunlight or by contact with the air, they eventually become buoyant and disperse upward. Before this upward dispersal occurs, however, high vapor concentrations can form downwind of an unignited spill at or near ground level. High-expansion foam can be used to reduce this vapor concentration by adding heat from the water in the foam to the LNG vapors as they pass through the foam blanket. Because of the induced buoyancy, the application of high-expansion foam can reduce downwind gas concentrations at ground level. Expansions in the range of 750:1 to 1000:1 have been found to provide the most effective dispersion control, but the higher expansions can be adversely affected by wind. However, as with fire control, ability to control vapor dispersion varies among different foams and should be demonstrated by tests.

A-3-4.1

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

A-3-4.2

LNG Fire and Vapor Control Reference Publications.

1. American Gas Association Project IS-3-1, “LNG Spills on Land,” November 15, 1973.
2. American Gas Association Project IS-100-1, “An Experimental Study on the Mitigation of Flammable Vapor Dispersion and Fire Hazards Immediately Following LNG Spills on Land,” February 1974.
3. Gremeles, A. E., and Drake, E. M., “Gravity Spreading and Atmospheric Dispersion of LNG Vapor Clouds,” Fourth International Symposium on Transport of Hazardous Cargoes by Sea and Inland Waterways, Jacksonville, FL, October 1975.
4. Humbert-Basset, R. and Montet, A., “Flammable Mixture Penetration in the Atmosphere from Spillage of LNG,” Third International Conference on LNG, Washington, DC, September 1972.
5. “Liquefied Natural Gas/Characteristics and Burning Behavior,” Conch Methane Services, Ltd., 1962.
6. “LNG Vapor Concentration Reduction and Fire Control with MSAR High Expansion Foam,” Mine Safety Appliances Research Corp., Evans City, PA.
7. Schneider, Alan L., “Liquefied Natural Gas Safety Research Overview,” National Technical Information Service, Springfield, VA, December 1978.
8. Welker, J. R., et al., “Fire Safety Aboard LNG Vessels,” January 1976.
9. Wesson, H. R., Welker, J. R., and Brown, L. E., “Control LNG Spill Fires,” *Hydrocarbon Processing*, December 1972.

This paper contains 105 additional references on many aspects of LNG safety research including use of high-expansion foam on LNG.

A-3-4.3

Application rates are generally established by specific fire tests such as that in A-1-10.5(d) where the equipment, water supply, fuel, and physical and chemical makeup of the candidate foam concentrate is carefully controlled. While these tests can be useful for comparing various foams, they often give minimum application rates because they are conducted under ideal weather conditions with no obstructions or barriers to fire control. The final design rates are generally 3 to 5 times the test rates. Thus, the rates can vary significantly from one foam agent to another.

A-3-4.5

Arrangement. The minimum foam depth at any point in the hazard area will vary, but most designs have attempted to obtain 11/2 ft to 3 ft (0.45 m to 1.5. m) of foam depth over the LNG spill area within the time established in the analysis.

Appendix B Referenced Publications

B-1

The following documents or portions thereof are referenced within this standard for informational purposes only and are thus not considered part of the requirements of this standard unless also listed in Chapter 5. The edition indicated here for each reference is the current edition as of the date of the NFPA issuance of this standard.

B-1.1 NFPA Publications.

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

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1996 edition.

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, 1996 edition.

NFPA 72, *National Fire Alarm Code®*, 1996 edition.

NFPA 231C, *Standard for Rack Storage of Materials*, 1998 edition.

B-1.2 Other Publication.

D. W. Johnson et al., *Control and Extinguishment of LPG Fires*, Applied Technology Corp., DOEEV-6020-1, August 1980.

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