

# NFPA 11A

## Medium- and High-Expansion Foam Systems

### 1988 Edition



## NOTICE

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

For information on the procedures for requesting Technical Committees to issue Formal Interpretations, proposing Tentative Interim Amendments, proposing amendments for Committee consideration, and appeals on matters relating to the content of the document, write to the Secretary, Standards Council, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

A statement, written or oral, that is not processed in accordance with Section 16 of the Regulations Governing Committee Projects shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

Users of this document should consult applicable Federal, State and local laws and regulations. NFPA does not, by the publication of this document, intend to urge action which is not in compliance with applicable laws and this document may not be construed as doing so.

### Policy Adopted by NFPA Board of Directors on December 3, 1982

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

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

---

**Licensing Provision** — This document is copyrighted by the National Fire Protection Association (NFPA).

**1. Adoption by Reference** — Public authorities and others are urged to reference this document in laws, ordinances, regulations, administrative orders or similar instruments. Any deletions, additions and changes desired by the adopting authority must be noted separately. Those using this method are requested to notify the NFPA (Attention: Secretary, Standards Council) in writing of such use. The term "adoption by reference" means the citing of title and publishing information only.

**2. Adoption by Transcription** — **A.** Public authorities with lawmaking or rule-making powers only, upon written notice to the NFPA (Attention: Secretary, Standards Council), will be granted a royalty-free license to print and republish this document in whole or in part, with changes and additions, if any, noted separately, in laws, ordinances, regulations, administrative orders or similar instruments having the force of law, provided that: (1) due notice of NFPA's copyright is contained in each law and in each copy thereof; and, (2) that such printing and republication is limited to numbers sufficient to satisfy the jurisdiction's lawmaking or rulemaking process. **B.** Once this NFPA Code or Standard has been adopted into law, all printings of this document by public authorities with lawmaking or rulemaking powers or any other persons desiring to reproduce this document or its contents as adopted by the jurisdiction in whole or in part, in any form, upon written request to NFPA (Attention: Secretary, Standards Council), will be granted a nonexclusive license to print, republish, and vend this document in whole or in part, with changes and additions, if any, noted separately provided that due notice of NFPA's copyright is contained in each copy. Such license shall be granted only upon agreement to pay NFPA a royalty. This royalty is required to provide funds for the research and development necessary to continue the work of NFPA and its volunteers in continually updating and revising NFPA standards. Under certain circumstances, public authorities with lawmaking or rulemaking powers may apply for and may receive a special royalty when the public interest will be served thereby.

**3. Scope of License Grant** — The terms and conditions set forth above do not extend to the index to this document.

(For further explanation, see the Policy Concerning the Adoption, Printing and Publication of NFPA Documents which is available upon request from the NFPA.)

---

### Statement on NFPA Procedures

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

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

**INSIDE,  
THE PROFESSIONAL  
RESEARCH,  
REVIEW,  
OPINION,  
DISCUSSION  
AND REVISION  
YOU  
ORDERED FROM  
NFPA**



**NATIONAL FIRE PROTECTION ASSOCIATION**

© 1988 NFPA, All Rights Reserved

**NFPA 11A**  
**Standard for**  
**Medium- and High-Expansion Foam Systems**  
**1988 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 9-12, 1987 in Portland, Oregon. It was issued by the Standards Council on December 2, 1987, with an effective date of December 22, 1987, and supersedes all previous editions.

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

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

**Origin and Development of NFPA 11A**

Work on this standard commenced in 1964. Several drafts were prepared by the 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 it 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.

### Technical Committee on Foam

**Richard F. Murphy, Chairman**  
Exxon Research & Engr. Co.  
Rep. API

**Laurence D. Watrous, Secretary**  
Professional Loss Control, Inc.

**Wayne E. Ault**, Rolf Jensen & Associates, Inc.  
**Francis X. Bender**, Safety Engineering Consultants  
**William G. Boyce**, U.S. Coast Guard  
**Layard E. Campbell**, Reliable Automatic Sprinkler Co., Inc.  
Rep. NFSA  
**William M. Carey**, Underwriters Laboratories Inc.  
**H. Ray Coleman**, San Francisco, CA  
**F. L. Deacon**, Kemper Group  
Rep. AAI  
**Arthur R. Dooley, Jr.**, Arthur R. Dooley & Son, Inc.  
Rep. NAFED  
**Robert H. Fritz**, M. W. Kellogg Co.  
**Victor G. Geihlsler**, Industrial Risk Insurers  
**Desmond Hird**, Angus Fire Armour Ltd.  
**Alan L. Holder**, LA Power & Light Co.  
Rep. EEI

**John A. Krembs**, M & M Protection Consultants  
**Norman R. Lockwood**, Washington Crossing, PA  
**Giorgio Marini**, Bari, Italy  
**Carlos M. Mendes**, Levitt-Safety Ltd.  
Rep. FEMI of Canada  
**Robert C. Merritt**, Factory Mutual Research Corp.  
**James F. O'Regan**, Feecon Corp.  
**John M. Poulson**, Union Carbide Corp.  
**John F. Riley**, Ansul Co.  
Rep. FEMA  
**L. E. Rivkind**, Mearl Corp.  
**Sturgis L. Stentz**, Costa Mesa, CA  
**B. J. Walker**, The FPE Group  
**William P. Wheeler**, Mobil Research & Development Corp.  
Rep. NPRA  
**H. E. Wolff**, Valley Forge, PA

#### Alternates

**William Biscontini**, Walter Kidde  
(Alternate to J. Riley)  
**Thomas M. Child, Jr.**, Kemper Group  
(Alternate to F. L. Deacon)  
**W. G. Garrison**, M & M Protection Consultants  
(Alternate to J. A. Krembs)  
**Richard A. Gross**, Industrial Risk Insurers  
(Alternate to V. G. Geihlsler)  
**James W. Hatcher**, Underwriters Laboratories Inc.  
(Alternate to W. M. Carey)

**Dale W. Kent**, 3M Co.  
(Alternate to 3M Co. Rep.)  
**Francisco N. Nazario**, Exxon Research & Engr. Co.  
(Alternate to R. F. Murphy)  
**Charles Pappas**, Grinnell Fire Prot System Co. Inc.  
(Alternate to L. Campbell)  
**Gary Taylor**, Rolf Jensen & Associates, Inc.  
(Alternate to W. E. Ault)  
**Klaus Wahle**, U.S. Coast Guard  
(Alternate to W. G. Boyce)

#### Nonvoting

**Donald M. Johnson**, San Bruno, CA  
Rep. Flammable and Combustible Liquids Committee

**Mark T. Conroy**, NFPA Staff Liaison

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

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.

## Contents

<b>Chapter 1 General</b>	<b>11A- 4</b>
1-1 Scope	11A- 4
1-2 Purpose	11A- 4
1-3 History	11A- 4
1-4 Description	11A- 4
1-5 Definitions and Units	11A- 5
1-6 General Information and Requirements	11A- 6
1-7 Personnel Safety	11A- 6
1-8 Specifications, Plans, and Approval	11A- 7
1-9 Operation and Control of Systems	11A- 8
1-10 Water, Foam Concentrate, and Air Supply	11A- 9
1-11 Foam-Generating Apparatus Location	11A- 9
1-12 Distribution Systems	11A- 9
1-13 Maintenance and Instructions	11A-10
<b>Chapter 2 Total Flooding Systems</b>	<b>11A-10</b>
2-1 General Information	11A-10
2-2 Enclosure Specifications	11A-10
2-3 Foam Requirements	11A-11
2-4 Maintenance of Submergence Volume for High Expansion Foam	11A-12
2-5 Overhaul	11A-12
2-6 Distribution	11A-12
<b>Chapter 3 Local Application Systems</b>	<b>11A-12</b>
3-1 General Information	11A-12
3-2 Hazard Specifications	11A-12
3-3 Foam Requirements for Flammable and Combustible Liquids and Solids	11A-12
3-4 Foam Applications for Liquefied Natural Gas (LNG)	11A-13
<b>Chapter 4 Portable Foam-Generating Devices</b>	<b>11A-13</b>
4-1 General Information	11A-13
4-2 Hazard Specifications	11A-13
4-3 Location and Spacing	11A-13
4-4 Foam Requirements	11A-13
4-5 Equipment Specifications	11A-13
4-6 Training	11A-13
<b>Chapter 5 Referenced Publications</b>	<b>11A-14</b>
<b>Appendix A Explanatory Notes</b>	<b>11A-14</b>
<b>Appendix B Referenced Publications</b>	<b>11A-21</b>
<b>Index</b>	<b>11A-21</b>

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

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

Information on referenced publications can be found in Chapter 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 this field are competent to design and install this equipment. It may be necessary for many of those charged with the purchasing, inspecting, testing, approving, operating, and maintaining of 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 prepared for use and guidance of those charged with the purchasing, designing, installing, testing, inspecting, approving, listing, operating, or maintaining of 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. The 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 semi-stable foam of about 1,000 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 has 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 cover the need for a foam more wind resistant than high expansion foam for outdoor applications.

**1-4\* Description.** Medium and high expansion foams are aggregations of bubbles 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. Such 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 is dependent to some extent on the rate of application and also 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 may be used on solid fuel and liquid fuel fires where some degree of in-depth coverage is necessary, e.g., for the total flooding of small enclosed or partially enclosed volumes such as engine test cells, transformer rooms, etc. It 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 may also be used on solid and liquid fuel fires but the in-depth coverage it can give is greater than for medium expansion foam. It is therefore 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 can also be used for the extinction of fires in enclosures where it may be dangerous to send personnel, e.g., in basement and underground passages. It may be used to control fires involving liquefied natural gases and LPG 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 may be limited because of the effects of wind and lack of confinement. Medium and high expansion foam have several effects on fires:

(a) When generated in sufficient volume, they can prevent free movement of air, necessary for continued combustion.

(b) When forced into the heat of a fire, the water in the foam is converted to steam, 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 of being cooled.

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

(e) When 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 liquefied natural gas (LNG) fires, high expansion foam will not normally extinguish a fire but it

reduces 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 may 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 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 is issued to outline 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.** For purposes of clarification, the following general terms used with special technical meanings in this standard are defined:

**Approved.** Acceptable to the "authority having jurisdiction."

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

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

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

**Foam Concentrate.** A concentrated liquid foaming agent as received from the manufacturer and approved for use in high expansion foam equipment.

**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 of 200:1 to approximately 1000:1. (See A-1-9.5.)

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

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

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

**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 of 20:1 to 200:1. (See A-1-9.5.)

**Shall.** Indicates a mandatory requirement.

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

**Standard.** A document containing only mandatory provisions using the word *shall* to indicate requirements. Explanatory material may be included only in the form of "fine print" notes, in footnotes, or in an appendix.

**1-5.2 Units.** Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). One unit (liter), outside of but recognized by SI, is commonly used in international fire protection. These units are listed in Table 1-5.2 with conversion factors.

**1-5.2.1** If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

Table 1-5.2

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

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



**1-5.2.2** The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

## **1-6 General Information and Requirements.**

**1-6.1** The information and requirements in Chapter 1 are generally common to all medium and high expansion foam systems.

**1-6.2 Mechanisms of Extinguishment.** Medium and high expansion foam extinguishes fire by reducing the concentration of oxygen at the seat of the fire, by cooling, by halting convection and radiation, by excluding additional air, and by retarding flammable vapor release.

**1-6.3 Use and Limitations.** 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.

**1-6.3.1** Some important types of hazards that medium and high expansion foam systems may satisfactorily protect include:

- (a) Ordinary combustibles
- (b) Flammable and combustible liquids
- (c) Combinations of (a) and (b)
- (d) Liquefied natural gas (high expansion foam only).

NOTE: Under certain circumstances it may 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.

**1-6.3.2** Ability to control or extinguish a fire in a given hazard may depend on such factors as expansion, drainage, and fluidity. These factors will vary with the concentrate, equipment, water supply, and air supply.

**1-6.3.3** Susceptibility of the protected hazard to water damage shall be evaluated.

**1-6.3.4** Medium and high expansion foam systems shall not be used on fires in the following hazards unless competent evaluation, including tests, indicates acceptability:

- (a) Chemicals, such as cellulose nitrate, that release sufficient oxygen or other oxidizing agents to sustain combustion.
- (b) Energized unenclosed electrical equipment. (See 1-7.1.5.)
- (c) Water-reactive metals such as sodium, potassium, NaK.
- (d) Hazardous water-reactive materials, such as triethyl-aluminum and phosphorous pentoxide.
- (e) Liquefied flammable gas.

**1-6.4 Types of Systems.** The types of systems recognized in this standard include:

- Total Flooding Systems
- Local Application Systems
- Portable Foam Generating Devices.

**1-6.5 Systems Protecting One or More Hazards.** Systems may be used to protect one or more hazards or groups of hazards using the same supply of foam concentrate and water except as provided in 1-6.5.1.

**1-6.5.1** Where, in the opinion of the authority having jurisdiction, two or more hazards may be simultaneously involved in fire by reason of their proximity, each hazard shall be protected with an individual system or the system shall be arranged to discharge on all potentially involved hazards simultaneously.

## **1-7 Personnel Safety.**

**1-7.1 Hazards to Personnel.** The discharge of large amounts of medium or high expansion foam may 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 and also under the effect of sprinkler discharge.

**1-7.1.1** Where possible, the relative location of foam discharge points to building exits shall be arranged to facilitate evacuation of personnel. Additional exits and other measures may be necessary to ensure safe evacuation of personnel.

**1-7.1.2** To reenter a foam-filled building, a coarse water spray may be used to cut a path in the foam. Personnel shall not enter the foam. The foam is opaque, and it is impossible to see when one is submerged. It is dangerous to enter a building in which there was a fire if one cannot see.

**1-7.1.3 Caution.** A canister-type gas mask shall not be worn in the foam. The chemicals of the canister may 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.

**1-7.1.4** Unenclosed electrical apparatus shall be de-energized upon system actuation unless by competent evaluation it has been deemed unnecessary.

**1-7.2 Electrical Clearances.** All system components shall be so located as to maintain minimum clearances from live parts as shown in Table 1-7.2.

As used in this standard, "clearance" is the air distance between medium or high expansion foam equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential. Since medium and high expansion foams are conductive, these clearances do not prevent conduction through foam. (See 1-7.1.5.)

The clearances given are for altitudes of 3,300 ft (1000 m) or less. At altitudes in excess of 3,300 ft (1000 m), the clearance shall be increased at the rate of 1 percent for each 330 ft (100 m) increase in altitude above 3,300 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 1-7.2, 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 1-7.2

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

Nominal Line Voltage (kv)	Nominal Voltage to Ground (kv)	Design BIL (kv)	Minimum Clearance* (in.)	mm
To 15	To 9	110	7	178
23	13	150	10	254
34.5	20	200	13	330
46	27	250	17	432
69	40	350	25	635
115	66	550	37	940
138	80	650	44	1118
161	93	750	52	1321
196-230	114-132	900	63	1600
		1050	76	1930
		1175	87	2210
		1300	98	2489
287-380	166-220	1425	109	2769
		1550	120	3048
		1675	131	3327
500	290	1800	142	3607
		1925	153	3886
500-700	290-400	2100	168	4267
		2300	184	4674

NOTE: Basic Insulation Level (BIL) values are expressed as kilovolts (kv), the number being the crest value of the full wave impulse test that the electrical equipment is designed to withstand.

\*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 following items 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 may be required to meet the approval of the authority having jurisdiction, and indicate how cost of testing is to be borne.

**1-8.2 Plans.** Where plans are required, their preparation shall be entrusted only to fully experienced and responsible persons.

**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 easily reproduced.

**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 detail on the system shall include sufficient 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 so that the adequacy of the quantity, flow rate, and distribution of the medium and high expansion foam generated can be determined. (See *Chapter 7 of NFPA 13, Standard for the Installation of Sprinkler Systems, for calculation procedures*.) Detailed information shall be submitted pertaining to the location and function of detection devices, operating devices, auxiliary equipment including stand-by power and electrical circuitry, if used. Sufficient information shall be indicated to identify properly the apparatus and devices used. Any special features shall be adequately explained.

**1-8.3 Approval of Plans.** Where plans are required, they shall be submitted to the authority having jurisdiction for approval before work starts.

**1-8.3.1** 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 up 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. (*See NFPA 13, Standard for the Installation of Sprinkler Systems.*)

**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 the 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 is 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 may be detected by human senses or by automatic means.

**1-9.2.1** Automatic detection shall be used for fixed systems.

*Exception: Automatic detection may be omitted only when approved by the authority having jurisdiction.*

**1-9.2.2** Automatic detection shall be by listed or approved method 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. (*See NFPA 72E, Standard on Automatic Fire Detectors.*)

**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. (*See applicable provisions of NFPA 72A, Standard for the Installation, Maintenance, and Use of Local Protective Signaling Systems for Guard's Tour, Fire Alarm, and Supervisory Service, for power supply requirements.*)

**1-9.3 Supervision.** Supervision of automatic detection and actuation equipment shall be provided and so arranged 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, alert personnel, and indicate failure of any supervised device or equipment. Such devices shall be of such a type and shall be provided in such numbers and 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 hazard to personnel may 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 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 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 may be required where the area is large, egress difficult, or when 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 provides approved positive operation independent of the automatic actuation, it may 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 with the system operation.

**1-9.5.7** All manual operating devices shall be identified 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 may 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 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 is 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).)] 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 in A-1-10.5.

**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 may be in separate tanks or compartments, in drums or cans on the premises, or available from an approved outside source within 24 hours.

**1-10.7 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 tightly closed 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. Consult the foam equipment manufacturer.

**1-10.9 Air Supply.** 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 Section 2-3.5 if test fire indicates that need.

**1-10.9.1** 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 so located and arranged 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 protected against fire exposure. Such protection may be in the form of insulation, fire-retardant paint, water spray, or sprinklers, etc. In certain applications additional generators may 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 may not be compatible with foam concentrate. 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 which 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 assure 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 shall be provided in the water line upstream of the water valve suitable for use with the proportioner and foam generator. Supplemental strainers may be used as recommended by the foam equipment manufacturer.

**1-12.3 Valves.** 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 deemed suitable for such use as a part of the system.

**1-12.3.1** Valves shall not be easily subject to mechanical, chemical, or other damage.

**1-12.4 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.

**1-12.4.1** Duct closures such as selector valves, gates, or doors shall be of the quick-opening type, allowing free passage of the foam. When located where they may 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.

**1-12.4.2** 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 shall include determination of any changes in physical properties of the foam concentrate that indicate any deterioration in quality. Regular service contracts with the manufacturer or installing company are recommended.

**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 when 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.** These 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.

**1-13.2.1** Any troubles or impairments shall be corrected at once by competent personnel.

**1-13.3 Instructions.** All persons who may be expected to inspect, test, maintain, or operate foam-generating apparatus shall be thoroughly trained and kept thoroughly trained in the functions they are expected to perform.

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

**2-1.2.2** Fires that can be controlled or extinguished by total flooding methods can be divided into three categories:

(a) surface fires involving flammable or combustible liquids and solids,

(b) deep-seated fires involving solids subject to smoldering, and

(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 in the previous chapter and with the additional requirements set forth in this chapter. 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, windows, etc., 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 a 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 assure proper performance.

**2-2.1.2** When 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 venting

so required shall consist of suitable openings, either normally open, or normally closed and arranged to open automatically when the system operates. When 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 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, sufficient medium or high expansion foam shall be discharged at a rate 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.** 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 may be considerably greater and shall be determined by tests.

**2-3.2.2 Medium Expansion.** Required depth over the hazard will vary with expansion. Depth shall be determined by tests. (See A-1-10 for guidance.)

**2-3.3 Submergence Volume for High Expansion Foams.** Submergence volume is defined as (1) the depth as specified in 2-3.2.1 multiplied by the floor area of the space to be protected, or (2) 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 may 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 may be required depending on the factors included in 2-3.5.

#### 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, nature and configuration of the hazard, 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, temperature effects on water retention, etc. The foam discharge

Table 2-3.4  
Maximum Submergence Time for High Expansion Foam Measured from Start of Foam Discharge\* (Minutes)

Hazard	Light or Unprotected Steel Construction		Heavy or Protected or Fire-resistant Construction	
	Sprinklered	Not Sprinklered	Sprinklered	Not Sprinklered
Flammable Liquids [Flash Points below 100°F (38°C)] having a vapor pressure not exceeding 40 psia (276 kPa)**	3	2	5	3
Combustible Liquids [Flash Points of 100°F (38°C) and above]**	4	3	5	3
Low Density Combustibles i.e., Foam Rubber Foam Plastics Rolled Tissue or Crepe Paper	4	3***	6	4***
High Density Combustibles i.e., Rolled Paper Kraft or Coated-Banded	7	5***	8	6***
High Density Combustibles i.e., Rolled Paper Kraft or Coated-Unbanded	5	4***	6	5***
Rubber Tires	7	5***†	8	6***†
Combustibles, in cartons, bags, fiber drums	7	5***	8	6***

Notes for Table 2-3.4

\*This is based on a maximum of 30-second delay between fire detection and start of foam discharge. Any delays in excess of 30 seconds shall be deducted from the submergence times in Table 2-3.4.

\*\*Polar solvents are not included in this table. Flammable liquids having boiling points less than 100°F (38°C) may require higher application rates. See NFPA 321, *Standard on Basic Classification of Flammable and Combustible Liquids*. Where use of high expansion foam is contemplated on these materials, the foam equipment supplier shall substantiate suitability for the intended use.

\*\*\*These submergence times may not be directly applicable to high-piled storage above 15 ft (4.6 m) or where fire spread through combustible contents is very rapid.

†High expansion foam protection without sprinkler protection is not recognized within the scope of NFPA 231D, *Standard for Storage of Rubber Tires*. NFPA 231D applies only to locations having more than 10,000 equivalent passenger tires.

rate shall be sufficient to satisfy the foam depth requirements and submergence times of Table 2-3.4, making 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 — cfm  
(m³/min)

V = submergence volume —  
cubic feet (m³)

- $T$  = submergence time — minutes  
 $R_s$  = rate of foam breakdown by sprinklers — cfm ( $\text{m}^3/\text{min}$ )  
 $C_N$  = 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 cfm per gpm of sprinkler discharge.  $S$  shall be 10 cfm/gpm (0.0748  $\text{m}^3/\text{min}$ )/(L/min).

$Q$  = Estimated total discharge from maximum number of sprinklers expected to operate—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, etc.

(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. Obviously 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.** 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.

**2-3.6.1** 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 may be reduced.

**2-4.1 Method.** The submergence volume may be maintained by continuous or intermittent operation of any or all of the generators provided.

**2-4.1.1** Arrangements and procedures shall be provided to maintain the submergence volume without waste of foam concentrate that may be needed in case of re-ignition.

**2-5\* Overhaul.** Overhaul procedures shall be carefully preplanned 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 and arranged to discharge foam directly onto the fire or spill.

**3-1.2 Uses.** Local application systems may 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, etc. For multiple-level or three-dimensional fire hazards where total building flooding is not practical, 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 previous chapters and with the additional requirements set forth in this chapter. 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 may spread.

**3-2.2\* Location of Hazard.** Local application medium and high expansion foam systems may be used to protect hazards located indoors, partly sheltered, or completely out-of-doors. 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.** 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.)

**3-3.2.1** 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<sup>2</sup> (111 m<sup>2</sup>). See NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, for information on fire protection requirements for LNG facilities.

**3-4.2\* System Design Considerations.** The determination of the high expansion foam system design depends on an analysis specific to the individual site. Since time to initiate actuation is a critical factor in LNG fire control, the analysis must consider effects of heat exposure on adjacent plant equipment. In many cases automatic alarms and actuation will be required for fixed systems.

**3-4.3\* Application Rate.** As established by test [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 for maintenance of fire control established in the test 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 so 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 may be integral to or separate from the foam generator. A separate foam concentrate supply may be provided for each unit, or solution may 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 the preceding chapters and with the additional requirements set forth in this chapter. Only listed or approved equipment and devices shall be used.

**4-2 Hazard Specifications.** Portable foam-generating devices may 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 with enough hose to reach the most distant hazard that 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 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 to the intended use. All power cables shall be sufficiently rugged to withstand abuse in service, 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 and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 **NFPA Publications.** National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA 11-1988, *Standard for Low Expansion Foam and Combined Agent Systems*

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

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

NFPA 59A-1985, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*

NFPA 70-1987, *National Electrical Code*

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

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

NFPA 231C-1986, *Standard for Rack Storage of Materials*

NFPA 231D-1986, *Standard for Storage of Rubber Tires*

NFPA 321-1987, *Standard on Basic Classification of Flammable and Combustible Liquids*

## Appendix A Explanatory Notes

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

**A-1-4 Refrigerated or cryogenic liquefied flammable gas fires** may be safely controlled and vapor concentrations downwind of unignited spills may be reduced by application of high expansion foam when their vapor density at ambient temperature and pressure is less than that of air.

High expansion foam should not be applied to refrigerated liquefied gas (LPG) fires unless careful consideration is given to the resulting possibly hazardous condition. Extinguishment may occur with evolution of heavier-than-air vapors beneath the foam blanket. These 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., Applied Technology Corp., August 1980, DOE/EV-6020-1.

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

(a) *Foam Generators.* At the present time, foam generators for medium and high expansion foam are of two types depending on the means for introducing air, namely, 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 air stream. The liquid films formed on the screen are distended by the moving air stream to form a mass of bubbles or medium or high expansion foam. The foam volume varies from about 20 to 1,000 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.

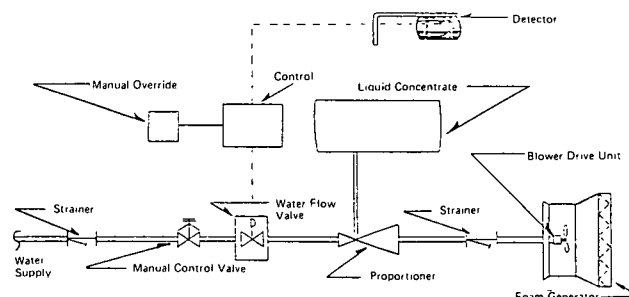


Figure A-1-9.5(a) Block Diagram of Automatic Medium- or High-Expansion Foam System.

(b) *Foam Generators — Aspirator Type.* These may 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(b).] These usually produce foam with expansion ratios not over 250:1.

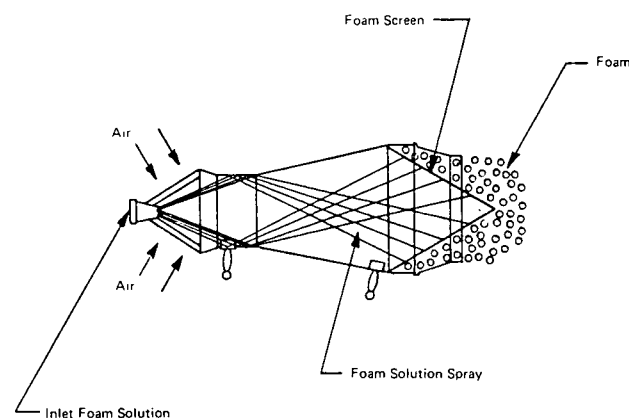


Figure A-1-9.5(b) Aspirating-type Foam Generator.

(c) *Foam Generators — Blower Type.* These may be fixed or portable. The foam solution is discharged as a spray onto screens through which an air stream developed by a fan or blower is passing. The blower may 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(c).]

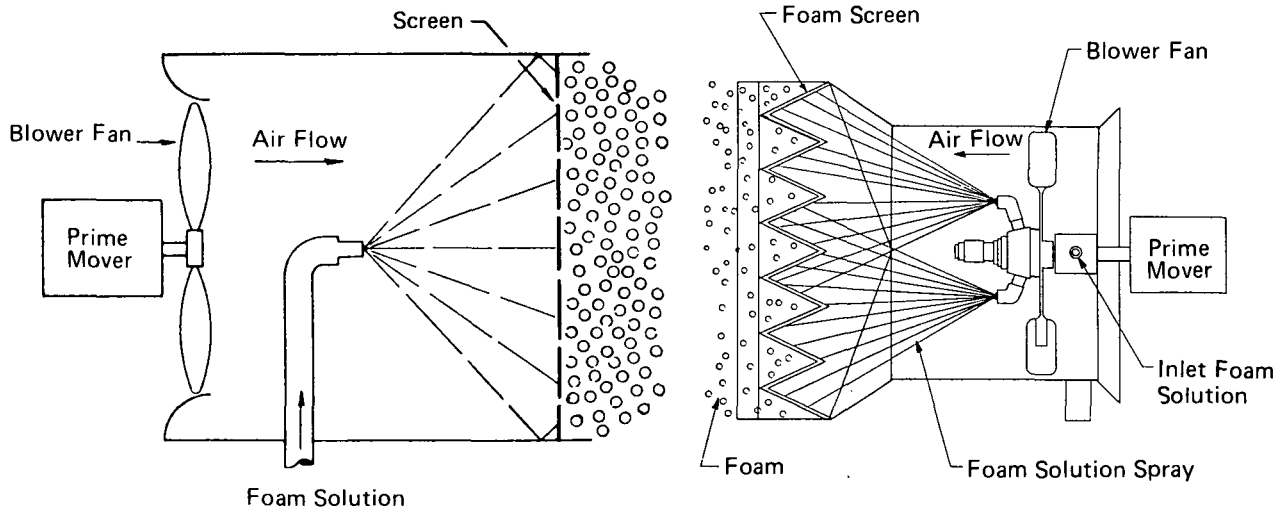


Figure A-1-9.5(c) Blower-type Foam Generators.

**A-1-10.5(a) Fire Performance Test for Class A Materials.** The purpose of this test is to provide a reproducible Class A fire situation where foam should be required to move a substantial distance at a slow rate to 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 cfm 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 may 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 foam transit time desired. 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 a stack of eight standard 4 × 4 ft (1.22 × 1.22 m) hardwood pallets dried to a moisture content between 5 and 8 percent, set on suitable noncombustible supports not over 24 in. (610 mm) above the floor. Beneath the pallets should be a 10-sq ft (0.93-m<sup>2</sup>) 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 should reach 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 time determined as the foam transit time.

The minimum foam transit time should be 12 minutes (150 percent of maximum submergence time, 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.

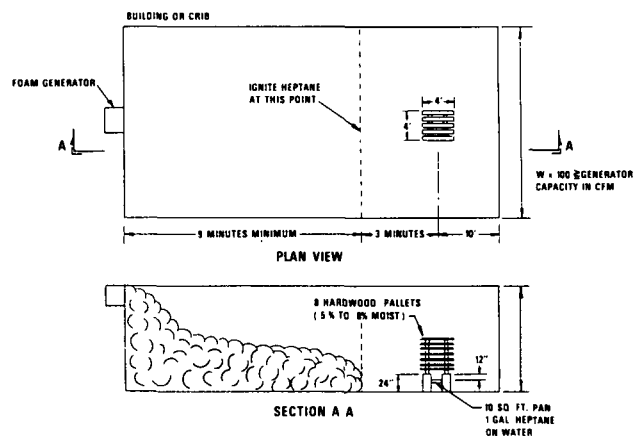


Figure A-1-10.5(a) Fire Performance Test.

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

1. Mix foam solution.
2. Fill foam solution can with solution.
3. Weigh foam can and thread onto apparatus.
4. Apply 25 psi (172 kPa) air pressure to liquid.
5. Start blower and adjust damper to approximately  $\frac{1}{3}$  opening. (May have to adjust later to obtain the desired expansion ratio.)
6. Open solenoid. Adjust liquid pressure to 15 psi (103 kPa) using liquid metering valve. (May have to readjust later.)
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 mL used. (1 g is approximately 1 mL.)
10. Record liquid drainage in mL at 1-minute intervals for 5 minutes, then at 10-minute intervals.
11. Plot time versus percent drained and record expansion ratio.

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

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

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

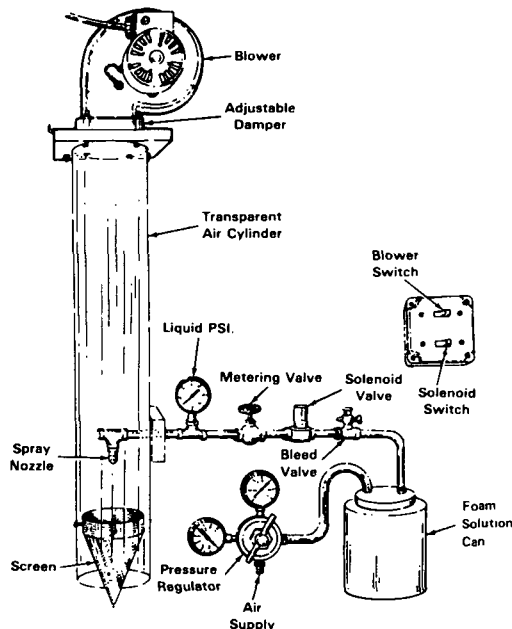
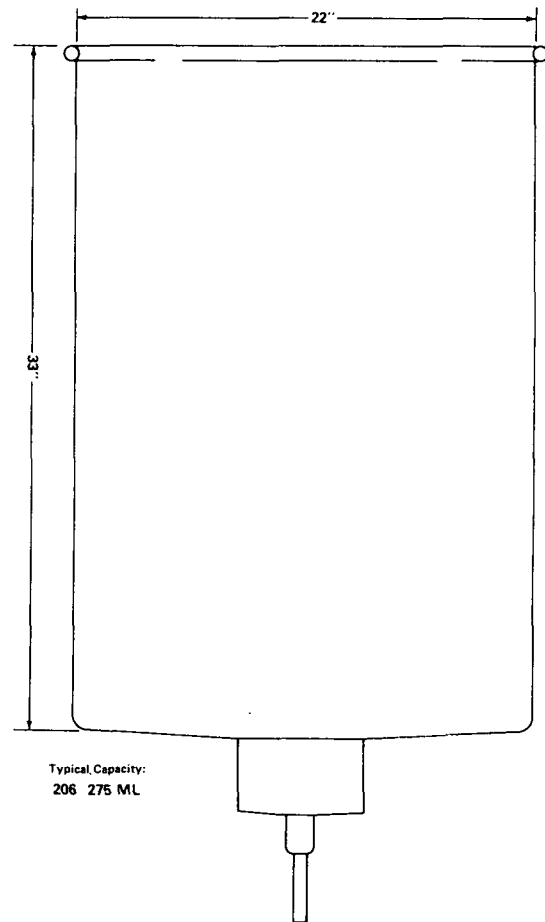


Figure A-1-10.5(b)(1) High Expansion Foam Quality Test Generator.



NOTE: Drum dimensions may vary  $\pm 5$  percent from the typical values shown.

Figure A-1-10.5(b)(2) Typical Drainage Drum for High Expansion Foam Expansion and Drainage Test.

(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 to 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 is 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 cfm of the foam generator used in the test. The height of the side of the pen or building is 10 ft (3 m). If the fluidity of the foam permits, the height may 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 is set 10 ft (3 m) from the end opposite the fire. The distance between the foam generator and the fire is as required to give the foam transit time desired. Foam is 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-sq ft (4.6-m<sup>2</sup>) 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 may be run for a maximum of 15 minutes.

The results of these tests are presented in the following tabulation:

Foam Type								
Test No.	Fire Type	Time Generator Started After Ignition, Min: Sec	Time to Cover Pan, Min: Sec	Inlet Pressure, PSI	No Visible Flame, Min: Sec	Fire Control, Min: Sec	Fire Extinguished, Min: Sec	Generator Off, Min: Sec
—	—	—	—	—	—	—	—	—

#### (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.

(i) Fire control time is the elapsed time from the beginning of foam application until the average radiation levels 1½ pool widths from the pool center measured in the crosswind direction, have reached 10 percent of the initial steady state uncontrolled values.

(ii) Foam application rate is the expanded foam flow rate in cu ft per minute per sq ft of LNG surface area.

##### 3. Test Equipment.

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

(ii) Four wide-angle, water-cooled radiometers with continual recording instruments for each.

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

(iv) Stopwatches.

(v) Calibrated equipment for measuring water and foam concentrate flows or foam solution flows if premixed.

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

##### 4. Test Procedure.

(i) All test instrumentation must be checked or calibrated prior to conducting the tests.

(ii) 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.

(iii) Position radiometers as shown in Figure A-1-10.5(d).

(iv) As shown in Figure A-1-10.5(d), center a single foam generator along the upwind side of the pool. A single foam application rate must be established and may not 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.

(v) Monitor and record the water flow and foam concentrate flow, or the solution flow, if premixed, to assure proper proportioning and application rates.

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

(vii) At least five gal per sq ft of LNG with a storage temperature not warmer than -151°C (-240°F) with 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.

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

(ix) Commence foam application and measure the fire control time.

(x) Once control is established, determine the application rates for maintenance of fire control 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. Repeat for a minimum of three cycles.

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

(i) Date and time of tests.

(ii) Location of tests.

(iii) Testing agency.

(iv) Model of equipment and materials tested.

(v) 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.

(vi) Initial LNG analysis before discharge into pit.

(vii) Depth of LNG in pit.

(viii) Foam generator performance data.

(ix) Data for all recording and measuring devices.

(x) Pit dimensions, orientation, and test set-up.

(xi) Application rates, expansion ratios, and supporting measurements.

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

**A-1-10.8** Exposure of the foam concentrate to the atmosphere may cause evaporation of some or all components of the concentrate and, in some cases, may cause crusting of the agent. This is exaggerated when a tank with an open vent is located in an area where the temperature fluctuates. For example, sunlight striking a

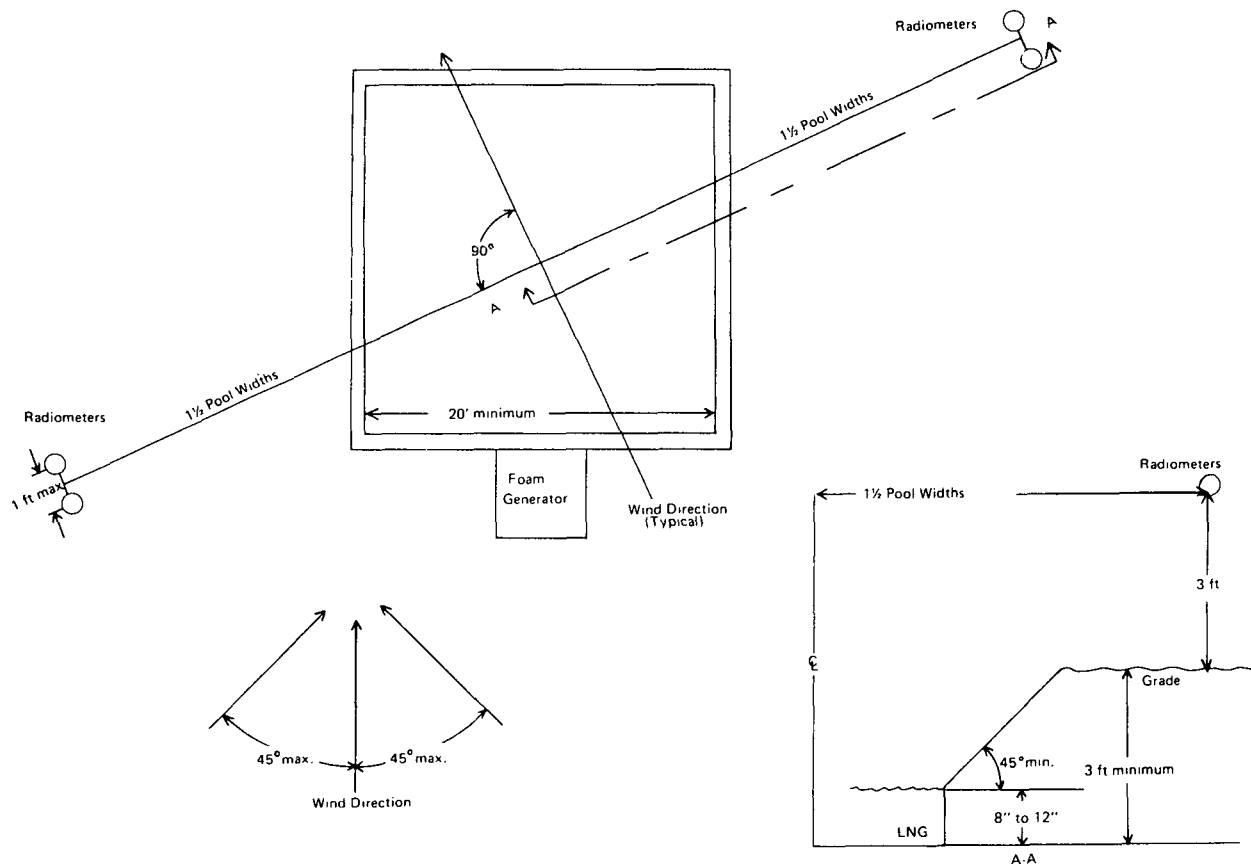


Figure A-1-10.5(d) Test Pit.

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 may 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, 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-sq ft (4.65-m<sup>2</sup>) N-heptane fire using 100 gal (379 L) of fuel. The test fire should be shielded to ensure flame impingement on the generator.

**A-1-13.1.4** Weekly recorded inspections of medium and high expansion foam systems should be made. Items to be checked include the following, as applicable:

*Foam Control Room, Including Foam Concentrate Supply System:*

- (a) Foam concentrate pumps, tanks, and lines checked for leaks or damage? Concentrate level in tanks normal?
- (b) Concentrate pumps operating properly?
- (c) All manually operated shutoff valves for the system properly positioned and locked?
- (d) Central panel lights operating properly?
- (e) All disconnects in the control panel in ON position?
- (f) Water supply pressure and flow rate normal?
- (g) Batteries fully charged? Liquid level normal?
- (h) Fire alarm and trouble alarms tested? Silence switches in normal position?
- (i) All supervised functions checked for proper operation?

*Electric Foam Generators:*

- (j) All disconnect switches in the ON position and locked?

*Sprinkler Water Supply and Alarms:*

- (k) Water pressure on sprinkler risers normal?
- (l) Water flow alarms tested?
- (m) All manually operated shutoff valves locked open?

*Protected Area:*

- (n) All closures operating properly?

**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.**

**Given:** *Building Size* — 100 ft × 200 ft × 30 ft high  
*Building Construction* — Light bar joist, Class I steel deck roof, adequately vented. Masonry walls with all openings closable.  
*Sprinkler Protection* — Wet system 10 ft × 10 ft spacing. 0.25 gpm/sq ft density.  
*Occupancy* — Vertically stacked unbanded rolled Kraft paper 25 ft high.

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

**Calculation:**

**Foam Depth**  
 Depth =  $25 \times 1.1 = 27.5$  ft  
 (This is greater than minimum cover of 2 ft.)

**Submergence Volume**  
 $V = 100 \times 200 \times 27.5 = 550,000$  cu ft

**Submergence Time**  
 $T = 5$  minutes (from Table 2-3.4)

**Rate of Foam Breakdown by Sprinklers**  
 $S = 10$  cfm/gpm [from 2-3.5.2(b)]  
 $Q = \text{No. of heads} \times \text{area/head} \times \text{density}$   
 $= 50 \times (10 \times 10) \times 0.25 = 1250$  gpm  
 $R_s = S \times Q = 10 \times 1250 = 12,500$  cfm

**Normal Foam Shrinkage**  
 $C_N = 1.15$  [from 2-3.5.2(c)]

**Leakage**  
 $C_L = 1.2$  (assumption)

**Total Generator Capacity**

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

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

$$R = 169,000 \text{ cfm}$$

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

**Sample Calculation Using SI Units.**

*Building Size* — 30.5 m × 61 m × 9.1 m high.

*Sprinkler Protection* — Wet System 3 m × 3 m spacing, 10.2 L/min/m<sup>2</sup> density.

*Occupancy* — Vertically stacked unbanded rolled Kraft paper 7.6 m high.

**Calculation:**

**Foam Depth**  
 Depth =  $7.6 \times 1.1 = 8.4$  m

**Submergence Volume**  
 $V = 30.5 \times 61 \times 8.4 = 15,628$  cu m

**Submergence Time**  
 $T = 5$  minutes (from Table 2-3.4)

**Rate of Foam Breakdown by Sprinklers**  
 $S = 0.0748$  m<sup>3</sup> • min/L • min [see 2-3.5.2(b)]  
 $Q = \text{No. of heads} \times \text{area/head} \times \text{density}$   
 $= 50 \times (3 \times 3) \times 10.2 = 4590$  L/min  
 $R_s = S \times Q = 0.0748 \times 4590 = 343$  m<sup>3</sup>/min

**Normal Foam Shrinkage**  
 $C_N = 1.15$  [see 2-3.5.2(c)]

**Leakage**  
 $C_L = 1.2$  (assumption)

**Total Generator Capacity**

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

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

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

**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, con-

templating the increased rate of foam escape as its fluidity is increased by anticipated sprinkler discharge.

Such leakage through drains, trenches, under doors, around windows, etc., can be minimized by use of suitable automatic closures, seals, or mechanisms. Additional generator capacity shall 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 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, hardboard.

(b) If the material involved is liable to deep-seated fires, such as furniture, packaged material, fibers, rolls of paper, etc., 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 may cause reignition.

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

**A-2-5 Overhaul.** 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 shall 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 shall 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 may 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 is due in part to the foam barrier that 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. Control was established with expansion ratios greater than 250:1 although an expansion ratio of about 500:1 proved most effective in the AGA test. 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 may 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 happens, however, high vapor concentrations may 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 may 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-3-4.2 LNG Fire and Vapor Control Reference Publications.**

1. American Gas Association Project IS-3-1, "LNG Spills on Land," Nov. 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," Feb. 1974.
3. "LNG Vapor Concentration Reduction and Fire Control with MSAR High Expansion Foam," Mine Safety Appliances Research Corp., Evans City, PA 16033, undated.

4. Welker, J.R., et al., "Fire Safety Aboard LNG Vessels," Jan. 1976.

5. Wesson, H.R., Welker, J.R., and Brown, L.E., "Control LNG Spill Fires," Hydrocarbon Processing, Dec. 1972.

6. "Liquefied Natural Gas/Characteristics and Burning Behavior," Conch Methane Services, Ltd., 1962.

7. Humbert-Basset, R. and Montet, A., "Flammable Mixture Penetration in the Atmosphere from Spillage of LNG," Third International Conference on LNG, Washington, DC, Sept. 1972.

8. 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, Oct. 1975.

9. Schneider, Alan L., "Liquefied Natural Gas Safety Research Overview," National Technical Information Service, Springfield, VA, Dec. 1978.

NOTE: 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 Rate.** 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 make up of the candidate foam concentrate is carefully controlled. While these tests may 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 may 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 1½ to 3 ft (0.45 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 thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

### B-1.1 Other Publications.

ASTM Publications are available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E 380-1979, *Standard for Metric Practice*

## Index

© 1988 National Fire Protection Association, All Rights Reserved.

The copyright in this index is separate and distinct from the copyright in the document which it indexes. The licensing provisions set forth for the document are not applicable to this index. This index may not be reproduced in whole or in part by any means without the express written permission of the National Fire Protection Association, Inc.

**-A-**

Actuation, methods of ..... 1-9.1

Air supply ..... 1-10.9

Alarms ..... 1-9.4

Approvals ..... 1-8.3, 1-8.4

**-D-**

Description of foams ..... 1-4, A-1-4

Detection of fires ..... 1-9.2

Distribution systems ..... 1-12

Ducts ..... 1-12.4

**-E-**

Electric power supply ..... 4-5.2

Electrical clearances ..... 1-7.2

Exposure protection ..... 1-11.2, A-1-11.2

Extinguishment, mechanisms for ..... 1-6.2

**-F-**

Flammable and combustible liquids and solids

  Foam requirements for ..... 3-3

  Local application systems ..... 3-3

Foam concentrate

  Definition ..... 1-5

Quality ..... 1-10.5, A-1-10.5

Quantity ..... 1-10.4

Reserve supply of ..... 1-10.6

Storage ..... 1-10.7, 1-10.8, A-1-10.8

Foam generators ..... see also Portable foam-generating devices

  Location of ..... 1-11, A-1-11

  Types of ..... A-1-9.5

Foam solution

  Definition ..... 1-5

**-G-**

Gas masks, canister-type ..... 1-7.1.3

**-H-**

Hazards ..... 1-6.3.1, 1-6.3.4

  Systems protecting one or more ..... 1-6.5

  Personnel ..... 1-7.1

High-expansion foam

  Definition ..... 1-5

  Total flooding systems

    Depth ..... 2-3.2.1

    Rate of Discharge ..... 2-3.5.2, A-2-3.5

    Submergence time ..... 2-3.4, A-2-3.4

    Submergence volume ..... 2-3.3, 2-4, A-2.4

History of foam ..... 1-3

Hose, portable foam-generating devices ..... 4-5.1



<b>-I-</b>		
Inspection of systems	1-11.1, 1-13.1, A-13.1.4	
Installations	1-12.2	
Approval of	1-8.4	
Instructions	1-13.3	
<b>-L-</b>		
Leakage	2-3.5.2(d), A-2-3.5.2(d)	
Total flooding systems	2-2.1	
Limitations of foams	1-6.3	
Liquefied Natural Gas (LNG)		
Local application systems	3-4, A-3-4	
Application rate	3-4.3, A-3-4.3	
Foam system arrangement	3-4.5, A-3-4.5	
System design considerations	3-4.2, A-3-4.2	
Local application systems	Chap. 3	
Flammable and combustible liquids and solids	3-3	
Hazard specifications	3-2, A-3-2	
Liquefied Natural Gas (LNG)	3-4, A-3-4	
<b>-M-</b>		
Maintenance of systems	1-11.1, 1-13.2	
Measurement, units of	1-5.2	
Medium-expansion foam	1-6.1	
Definition	1-5	
Depth	2-3.2.2	
Rate of discharge	2-3.5.1, A-2-3.5	
<b>-O-</b>		
Operating devices	1-9.5, A-1-9.5	
Operation and control of systems	1-9, A-1-9	
<b>-P-</b>		
Personnel safety	1-7	
Piping and fittings	1-12.1	
Arrangement and installation	1-12.2	
Plans	1-8.2	
Approval of	1-8.3	
Portable foam generating devices	Chap. 4	
Equipment specifications	4-5	
Foam requirements	4-4	
Hazard specifications	4-2	
Location and spacing	4-3	
Training	4-6	
Purpose of standard	1-2	
<b>-S-</b>		
Safety of personnel	1-7	
Scope of standard	1-1	
Specifications of systems	1-8.1	
Hazard, local application systems	3-2, A-3-2.2	
Hazard, portable foam generating devices	4-2	
Sprinklers, breakdown by	2-3.5.2(b), A-2-3.5.2(b)	
Storage, foam concentrate	1-10.7, 1-10.8, A-1-10.8	
Supervision of systems	1-9.3	
<b>-T-</b>		
Tanks, foam concentrate storage	1-10.8, A-1-10.8	
Tests of systems	1-8.4, 1-13.1, A-1-10.5, A-1-13.1.4	
Total flooding systems	Chap. 2	
Distribution	2-6	
Enclosure specifications	2-2	
Foam requirements	2-3, A-2-3	
Maintenance of submergence volume		
for high expansion foam	2-4, A-2-4	
Overhaul	2-5, A-2-5	
Rate of discharge	2-3.5, A-2-3.5	
Training	4-6	
Types of systems	1-6.4	
<b>-U-</b>		
Use of foams	1-6.3	
<b>-V-</b>		
Valves	1-12.3	
Ventilation, total flooding systems	2-2.1	
<b>-W-</b>		
Water		
Storage	1-10.3	
Quality	1-10.2	
Quantity	1-10.1	